# *GUARDIAN*

Discreet Self Defense Device

Senior Design 1 Fall 2016: Group 16

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Sponsored by: KnightGuard



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# I. Executive Summary

The following project goes into detail about our motivation, detailed plan, testing, and end results of what we are trying to accomplish. We work together with KnightGuard Corporation, a corporation determined on developing an undetectable, hands free, non-verbal self-defense device. Founded in 2015 by Thomas Bland, a UCF alumni from 1975 who has dedicated his time to make sure his clients will always be protected. The team at KnightGuard Corp plan to assist and provide relief for anybody from others who have criminal intentions. They work with law enforcement officials, military services, cell phones, and more devices. The main purpose for creating this company was to have handcuffs, not body bags. We chose to work with this team because we saw how they wanted to build a mechanism for a worthy cause, the need for a safe personal defense mechanism for everybody that is in harm's way.

We propose the idea of a small, easy to use defense mechanism that will be able to disorient potential assailants as well as warn nearby police stations that your person is in danger. We plan to do this using 3 different devices that act all together in order to bring about a cohesive working unit to protect the user. The 1st device will be used to mainly as the activator for both of the devices, where a signal would be sent out. The 2nd device will be used primarily as the repellant to the assailant, where a quick sharp sound will be emitted, as well as an LED to be emitted for testing. The 3rd device will mainly be used to call the police station, have their information pulled up, and show the location of user current location. In order to properly test that this works, we will have a new user input their information into a database, simulate an attack where the 1st device will activate and send a signal to both devices 2 and 3. Device 2 will then activate a quick sound and display the LED to signify that device 2 has received the signal. Device 3 will receive the same signal from device 1, send out another signal to a personal computer that holds the database, where it will pull up the information when first inputted as well as the phone’s last known location, and also relay a quick sound to signify that it has received device 1’s signal.

# II. Project Description

## 2.1 Project Motivation and Goals

Safety has become an increasingly larger issue in years past. The news shows everyday that people are getting hurt or they are hurting others, whether for their own safety or because they feel that they need to hurt others. The media outlets are almost constantly showing stories on how police are killing others because they fear for their safety, or that people will specifically target police officers and try to kill them, just over their profession. Everyday women and men face the dangerous possibility of being attacked, kidnapped, or raped. Particularly, women are being subjected to an increasing rate of sexual abuse and rape. According to the National Sexual Violence Resource Center, one in five women and one in sixteen men are sexually assaulted while in college and over ninety percent of the victims never report the crime which left them defenseless. Many people also face the chance to be robbed while leaving work, school, or even while simply outside walking. Recently in Orlando, a tourist was killed while trying to protect his wife during a robbery.

In many instances, the victim has no way to defend themselves, and can be left injured or even killed. Even if the victim has a way to defend themselves, there is a large possibility that for various reasons they will be unable to stop the attack, keeping the user in danger. If a pocket knife is used for defense, the victim may not be able to get to it and open their knife or even be able to grab it to defend against the assailant. Even if a gun is used, it has the possibility to jam or the victim will be disarmed before they can turn off the safely and use it. Pepper spray is a commonly used because it is easy to carry due to its size, but pepper spray is mostly only effective if sprayed directly into the attacker's face, and if unable to do so, the weapon is rendered useless. These are things people cannot rely on in some situations. When being attacked, arms and legs are often restrained so that they will be unable to run or grab their weapon. In both scenarios, a person who is in harm's way has little to no way of defending themselves if they are attacked. This being how things are nowadays, people want to be able to ensure the safety of themselves and their family and friends without any worry that their defense will be effective given any type of attack.

Our proposed project will be a way to reliably ensure the safety of the user, if it would need to be used. The project will not only provide safety of the user, but also peace of mind to their family and friends who may not be around to protect them. The devices that are planned to be created would be a discreet self-defense mechanism, that would only require limited movement to engage. The device will be lightweight, and have a low cost so as to be accessible by everyone. Once

engaged, the system would disable the attacker while being able to send a signal to a local police station or security company, alerting the authorities to the location of the attack, and allowing them to detain the attacker, thereby stopping the possibility of future victims. This will be done through two to three devices. One will be for activation, one for deployment and the third for signaling. The devices can be used by civilians who may fear the possibility of an attack, or even by police officers in taking down an assailant without resorting to killing them, taking more people away in handcuffs than in body bags.

## 2.2 Project Specifications

- Communication System
    - Secure, not able to be intercepted or hijacked
    - 1-time secure pairing between an individual's' devices
    - Pairing between system components
    - Able to send signal to local police station or security system
    - Able to send signal from 1st device to additional devices
- Microcontroller
    - Able to determine whether 1st device was activated intentionally or accidentally
    - Hold security codes for communication system
- 1st Device
    - Able to activate self-defense mechanism easily
    - Mechanism/programming to prevent false alarms
    - Able to send signal to additional securely paired devices
    - Waterproof up to 1m (IP67)
    - Completely sealed off aside from ability to swap out power supply
    - A power supply life of 12-24 months
        - Lifespan of about 2 years
    - Approximate weight of no more than 20 grams
- 2nd Device
    - Dimensions no more than 40x37x6 mm
    - Water resistant
    - Approximate weight of no more than 85 to 100 grams
    - Power supply life of 24+ hours
        - Lifespan of about 2 years
- Phone Application
    - Bluetooth capabilities

- Camera capabilities
- GPS tracking
- Access an external database
- Serial code authentication
- Standby mode if device 1 on only

# 2.3 House of Quality

The house of quality is a brief description of the engineering as well as marketing requirements that will be documented and as well as correlate their requirements. For the project being created, the primary concerns by the customer was to maintain a small size and the lifespan, with the other concerns being the cost of the product and easiness of use. In designing the device, weight and power consumption were the primary concerns, weight being directly correlated with the size of the device, and power being directly correlated with the lifespan of the project itself. Other concerned that were considered in designing of the project were the size of the components, cost to produce, and the quality of the components used in the device. The higher quality of the components would allow for an increased lifespan of the device with lower power consumption but would increase the cost to produce. The quality of the components used had little effect on the size and weight of the device. As the size of the product decreased, the cost to produce became lowered as well.

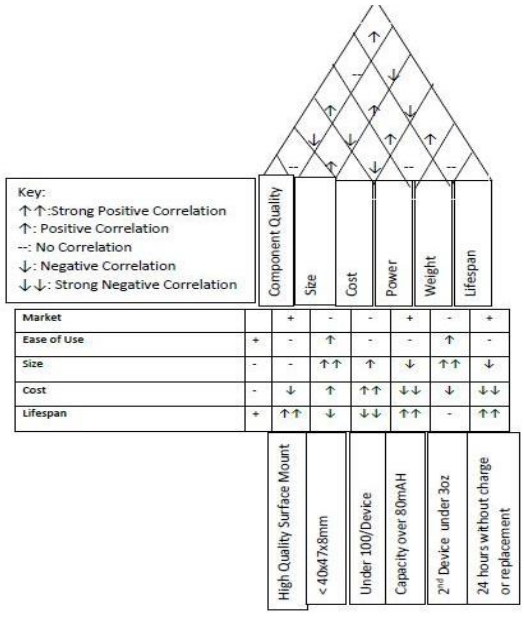


Figure 1: House of Quality

# III. Research Related to Project

## 3.1 Existing or similar products

Various products exist on the market that may involve a way to defend oneself against a perpetrator or a possible attacker. Some of these products require the user to have their hands free from any grasp in order for them to use it effectively. For example, a gun is a great self-defense weapon as it allows the user to incapacitate the attacker at an extended range but if the attacker were to come up behind the victim, surprise them, and were able to take the gun away, then that leaves the victim in even more trouble with the possibility of harm imminent. Another product that is a less lethal alternative is pepper spray. While pepper spray is a great deterrent against a possible attacker, the range is shorter than a gun and at the same time runs into the same problem with the gun. It is possible for the attacker to still sneak up behind the victim and do harm before the victim has time to do anything. The same thing goes for all self-defense weapons or products; the victim needs to have their hands free in order to activate the self-defense weapon. All of the products that are available to the average consumer require them to have their hands free and ready to go, as if the attacker were coming straight forward and they could see them from a mile away which in a majority of cases, that does not happen.

### 3.1.1 Self-Defense Based

#### Guns:

For the average person, a gun might seem like a scary tool. They see them on the news on how people use them for self-defense but what ends up happening is more often than not the person who got shot ends up in either critical condition or dead. The average person cannot live with themselves after having just shot somebody, regardless of how scary the situation is. The average gun (pistol for example) has a range of about 40 yards and requires a skilled shot to even hit a good grouping at the practice range, much less in a life or death situation that the average person might not be trained to handle. Even if a person had a gun and knew how to use it effectively, the person would have to go through a long process of obtaining a legal firearm due to background checks and wait periods. This process can take months and some people simply do not have that kind of time when they could get attacked at any time. A typically hand gun operates by when a person lines up the rear sight, the front sight, and the target, then a person either has the option to pull the trigger immediately or pull the hammer back, based on the model of the handgun. The model of the handgun determines how much

pressure is needed on the trigger pull, whether it be from 3lbs to 10lbs. Once a person pulls the trigger, the firing pin at the back of the gun is release which strikes the primer on the back of the cartridge. This causes the powder inside of the cartridge to ignite and fire the projectile out of the gun. After the projectile has been fired, the recoil of the gun is then used to push the slide back, allowing the gun to load the next cartridge into the chamber. A typical hand gun has around 15 rounds in a magazine and depending on the model, is either a 9mm or a 45 caliber bullet.

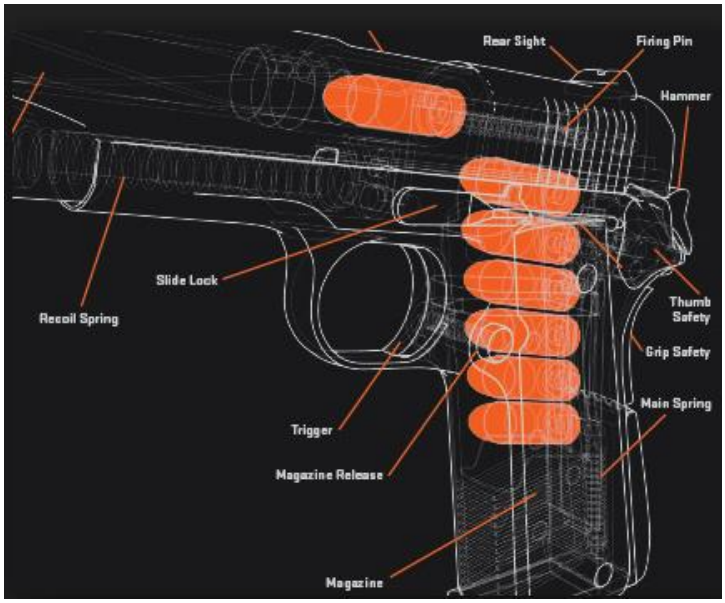


Figure 2:Layout of a typical hand gun

## Pepper spray:

Pepper spray is a great self-defense item. It allows the victim to incapacitate the attacker by spraying concentrated pepper extract, also known as Capsaicin: the primary chemical that makes a chili pepper hot, at the attacker. Pepper spray is, on average, between 500,000 and 15,000,000 on the Scoville scale, the international rating for how hot a chili pepper is; for example, a jalapeno pepper is between 3,500 and 10,000 Scoville and a habanero chili is between 100,000 and 350,000 Scoville. When the spray gets into someone’s eyes, throat, or nasal area, they are going to have a hard time breathing, snot will come out of their nose uncontrollably, and they will have a hard time seeing until the spray wears off. The problem with pepper spray is that it’s either in the victim's pocket or in their purse and if the attacker grabs the victim's arms, how are they going to be able to get to it. It also has to be taken into consideration that when a person activates the pepper spray can, they have to be accurate to within 10 feet or less or the person won’t be able to hit the attacker. The best course of action would be to use it when already being attacked or when the attacker it within range but more often than not

when the attacker is within 10 feet, it would be already too late. The pepper spray can work like any other aerosol can, in the sense that it works the same way as one. An aerosol can work by a series of chemical properties of elements such as nitrogen. For example, due to the fact that nitrogen has a very low bowling point and is a gas at room temperature, putting it under high amounts of pressure would force it to be a liquid. By doing this inside of a canister that contains the product, the nitrogen acts like a propellant when the pressure is released when a person presses the actuator.

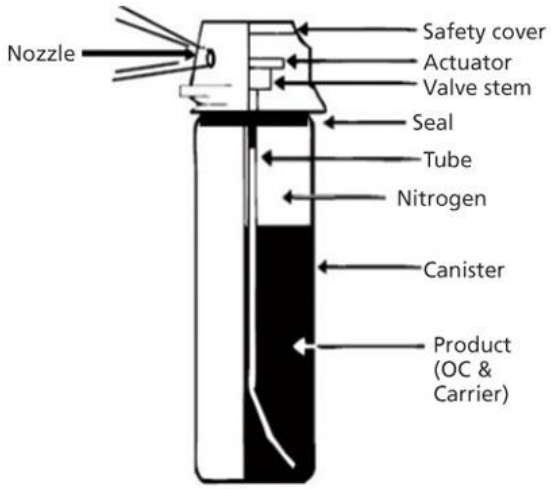


Figure 3: Cut out of a typical pepper spray can

## Tasers:

There are technically two ways to use a Taser effectively, the first way is to use it without the cartridge, meaning, when a user pulls the trigger, a visible high voltage electric arc jumps across the two electrodes on the end to the Taser. When the trigger is pulled, and pressed on the skin of an attacker, it sends a high voltage current through the attacker causing immense pain to the target area but it will not work as well when the cartridge is installed. With the cartridge installed, the user can fire two bolts at the attacker which will hopefully stick into the skin of them. With each trigger pull after the bolts are embedded, a high voltage current will pulse through the wires and cause the attacker to lose muscle control, causing them to fall to the ground and rendering them incapacitated. Again, like all of the other products, the Taser is typically in a pocket or in a purse and is not reachable it attacked from behind, and while a Taser is a good deterrent, it is almost useless without the cartridge, which is more effective at taking down an attacker. It works the same way as a gun but far less lethal, meaning, all a person has to do is hold it like a normal hand gun, line up the sights, and pull the trigger to release the probes. When the probes hit a target, it acts like a completed circuit and when a

person continuously holds down the trigger, it sends a maximum of 50,000 volts to the target along with 2.1 mA which is responsible for the take down of the target.


Figure 4: Layout of how a typical stun gun works

## Personal Alarm System:

Having a personal alarm system is great when a victim needs to notify the authorities immediately when don't have access to their phone or other communication device. Also, having a loud alarm system can be beneficial as it notifies every person in a given area that the victim is in need of help which may prevent the attacker from doing further harm to the victim. The advantages with a device like this is that it allows a separation of the phone and an alarm system just in case the attacker throws away the phone and the size would be small enough to put on a keychain which allows for ease of use. The problem with one of these devices is that it really offers no sort of protection for the victim as it's just a loud alarm and an alert that notifies the authorities but in reality the attacker can still kidnap the victim along with throwing away the device. Another product that can classified as a personal alarm system is a rape whistle. A rape whistle is just an ordinary whistle but instead of using it for commercial use, it is used as a defense mechanism by alerting everyone that is within ear shot of the whistle to know that the person is in trouble.

## Brass Knuckles/Similar Weapons:

Brass knuckles and other weapons that are able to be held in a similar way are great tools for defending oneself against an attacker. These particular weapons are light weight, relatively cheap and can successful ward of the attacker. They can easily be concealed in a purse or in a pocket and it does not take a skill person to use the weapons due to the fact that everybody knows how to punch. Problems may arise as these weapons are relatively short range depending on the reach of the person and if the attacker grabs the victim's at all during a struggle, the victim is no longer able to use the weapon. The weapons can also cause serious damage to the attacker; the attacker may deserve the blows they will receive from the weapon; the victim may feel guilty about how much damage one of the weapons can do. The brass knuckle works by augmenting a person's punch, meaning, it enhances the striking power of a person's punch to cause more damage it either a defensive or an offensive way. The user would put their four index fingers into the holes and then form a fist around the brass knuckle.

Figure 5: Generic Brass Knuckles

## Martial Arts/Self-Defense class:

Making a person body a living weapon is probably the best defense against an attacker should they come up behind a victim or attack them from the front. Knowing a martial art allows the victim to better defend themselves against a mugging, a kidnaping, or a possible rap. While marital arts are a great way to learn how to defend oneself, it also takes years of practice just to be able to counter most attacks. Taking a self-defense class would be in the best interest for the average consumer as it allows them to learn the basics in self-defense while not going in depth into a specific martial art. The problem with these specific methods is that they take time to learn and for some people time is money. Certain people

may not have the time to learn all the different techniques as they have busy schedules, etc. These people would rather have a plug-and-play sort of device that allows them to feel safe, same them time and money.

### 3.1.2 Application Products

While this is a new product, similar products have been made that also have a similar design in what they want to accomplish. With these applications that are out, it gives us a way to view how other apps work, while it also allows us the ability to see how our design is unique compared to others. A couple of those apps can be seen below.

#### bSafe:

bSafe is a personal safety application downloadable on both the iPhone and Android phones that creates a social network of individuals that nearby that can be notified in case of emergencies. This app comes with a free version that can contact authorities, but it also comes with a premium version where the user can notify a third party security company that will also receive the alert and can take action. The free version works all around the world however the premium version is only available in Norway, Sweden, and South Africa, with the United States version is soon to be up and available. Safety is the number one priority of this app, therefore it comes with several features that will give you that sense of security. A feature that is included in this app includes the ability to add an unlimited amount of friends into your safety net, allowing more people to check up on you in the event of an emergency. Another key feature is the SOS button, instantly alerting all friends that you are in danger and need assistance. It records sound and video as well as showing your location to the friends the alert was sent to. If you need to send an alert but are in a situation where noise is detrimental, there is also the option to turn off the noise while still having the app send a signal out to authorities and friends. Another feature is the ability to share your location wherever you are, regardless of the fact if you are in danger or not. [32]

#### SafeTrek:

SafeTrek is another app also downloadable for the iPhone and Android phones that sends a signal to the police in the event that the user is ever feeling that their safety is in trouble. The first 30 days of the app are free, and then can pay either $2.99 a month, or $29.99 for the entire year and works anywhere within the United States. This app works by having a single button on the user interface, and the user has 2 options. One option is to hold down the button until a keypad comes on the screen, and you enter the 4-digit pin that you make upon registration. This option is to make sure that you are safe. The other option is to release the button

and not enter in the 4-digit key. Doing this will send your information you made upon registration as well as your location to police. Police will then text and call you throughout the emergency to make sure you feel ok until they arrive on the scene. In the event that an ambulance or fire truck is needed, during the call or text, notify the police and the help will be sent. [33]

### 'Find My Friends' application:

The 'Find My Friends' mobile phone application works by letting the person contacts know where they are at all times, should they chose to activate that feature. It works by monitoring the GPS coordinates of the person's friends through the application and shows on a map where they are in the world. While this is the only function of the application, it is still a feature that is desired if a large group of people were to go on vacation together in an unfamiliar area. It allows the person's friends to see where they are if they ever get separated or worse. While the application does not send out any alerts, it still adds reassurance to people who want to know where they are, so long as they have their phone on them.

### Life alert:

While life alert may be mostly for senior citizens just in case if something were to happen to them, it still functions as a personal alert system to notify the authorities in the case of an emergency. When a senior citizen falls on the ground or if their house is getting robbed, they can simply press the button on the Life Alert device to notify authorities of the situation and can dispatch the proper personal to the person's location.

## 3.2 Components and Parts Selection

### Power Systems:

In designing the project's power systems a few things came to mind. Two separate power systems will have to be designed for the project. The first power system will be for the activator, and the sizing requires that the power system take up as little space as possible and still be able to operate. However, the activator only needs to supply current to a single communication device that will be left on standby or even kept off until the defense device needs to be activated. The second power system will be for the defense device, and can be larger in size than the activator’s power system. This power system will need to constantly on standby to receive the signal from the activator and will need to activate the defense mechanism upon activation. The power system will also be required to be chargeable, as everything will need to be sealed in to avoid temperament with the defensive mechanism. The

activator will require a long battery life to avoid changing every few hours of use, and the defense mechanism will require a battery life long enough not to need charging while the user is doing day to day activities, and will be away from the charger. Lifetime of the battery will be calculated using the following equation where T is the calculated lifetime in hours, C is the capacity of the battery in mAh, I is the current draw from the devices in mA, and the 0.7 representing the loss of current due to other factors in the device:

$$T = \frac{C}{I} * 0.7$$

The capacity of the battery determines the total amount of current or power than the battery can hold before it would need to be changed or recharged. If the capacity is small, then the lifetime of the battery is small as well. The two ways that can increase the capacity is to use a larger battery, or to use several different batteries in parallel. Here in lies the primary problems in increasing the capacity. The increase in capacity of the battery is directly proportional to the size increase of the battery. [30]

Many batteries are sold with a specified discharge rating. This rating is used to determine the safe current discharge rate of the battery in comparison to the capacity of the battery. [30]

$$I_{max} = DR * C$$

The formula above shows how to determine the maximum current discharge with I representing current, DR representing the discharge rate of the specific battery, and C representing the capacity of the battery. The battery can have two different discharge ratings associated with it. The primary discharge rating is for continuous use, and is standard for most devices running on the battery. The second discharge rating is for ten second bursts of current. The bursts are caused by the device using or creating pulses, as seen when a motorized device is set to accelerate. The second rating is higher than the continuous rating, but the current leaving at the rate it describes occurs far less often than the current for the continuous rating. [30]

The final factor that has to be taken into consideration when deciding on a battery to use is the internal resistance of the battery. The internal resistance of a battery changes over time and can be attributed to a small amount of voltage loss when testing the overall voltage of the battery when compared to the rated voltage of the battery. If the resistance is too high, then the voltage lost will increase and the device may not be able to operate. When the internal resistance reaches this point, the battery is considered to be at the end of its lifespan, and will need to be replaced. [30]

## Battery Types:

### Coin Cells:

A coin cells are a small round type of battery, that is used in small devices, typically electronic devices what do not require charging, and instead just replace the battery cells. They are made with alkaline, zinc, manganese, and most commonly, lithium. These types of batteries have a long shelf-life and are cheap, due to the high use among users. Because of a large internal resistance in the design of the circuit, they only provide a small continuous current, and is used more in pulsed devices, which allow for a larger current draw. [28]

The primary disadvantage with using this type of battery in many application is that most of them are non-chargeable. While this allows for the exclusion of a charging circuit in many devices, any time the battery is used up, they have to be disposed of and a new battery has to be placed within the device. The primary reason for the majority of this type of battery being non-chargeable is that, due to their design, they would have to be charged at a very slow rate, taking between ten to sixteen hours to charge. The design of the coin cells has no safety vent. Without the vent, the batteries could easily begin to swell if the charging current was higher, taking up more room, and causing a fear of the possibility of rupture. [31]

Another disadvantage is that due to their design, special holders have to be used, and the spring connection that is used in general batteries cannot be used. Another concern with battery cells are that they are very small. While this can also be considered an advantage, the disadvantage is they become easily swallowed. If they are passed through the body easily, then the worry is minimal. There are cases that the battery gets stuck, and that is where the main concern is. The batteries that get stuck in the body can cause internal tissue burns, which happens mostly if the battery becomes stuck in the esophagus, and is not removed immediately. [29]

### NiMH:

Nickel-metal hydride batteries use nickel for its positive electrode, hydrogen gas for its negative electrode, and a potassium hydroxide electrolyte. The design is similar to a widely used predecessor, but uses hydrogen gas instead of cadmium. The drawback of using the metal hydride over the cadmium batteries is that the NiCad batteries have a much larger discharge rate, but the lifetime of these batteries are shorter. The negative electrode of the NiMH batteries is made using an alloy of Lanthanum and some rare earth metals, as this reduces the oxidation of hydrogen. Because of the use of gas, the battery has to have a pressurized casing. Another way that the hydrogen gas is stored, is by using metallic compounds that have space in the lattice structure to accommodate the hydrogen.

A drawback to this low pressure design is that they have a shorter life, and the metal becomes corroded when exposed to the potassium hydroxide that is used as the electrolyte. [27]

The concept for the nickel-metal hydride batteries was patented in 1986. The idea came about from research that was being done in the seventies that was about using hydrogen as a form of alternative energy. Some of the alloys that were being used at the time were able to capture and release large amount of the hydrogen. With precise alloy constraints, they batteries became useful in standard conditions of room temperature and pressure. [27]

The most common use at the present time is within the automotive industry; more specifically, hybrid cars. When compared to other types of battery chemistries, the NiMH batteries have a larger range of temperatures in which it can still work. The energy density of the batteries is also double standard acid batteries and forty percent higher than its predecessor, the NiCad batteries. [27]

Charging of the NiMH batteries can be difficult because the battery is charged by forcing current through the battery, and does not have a constant voltage. The safest way to charge the battery is to use a small current over a long period of time. By extending the charge time, the battery can receive a full charge and does not require a sensor for the input current to be halted and prevent overcharging. Slight overcharging can still occur, which will lower the lifespan of the battery, but this can be prevented with a simple timer that will stop charging after around thirteen hours. A timer is still able to be used for faster charging that will take a maximum of five hours, but can damage the battery as the battery may not be fully discharged when charging begins. The fastest way to charge the battery is to use a temperature sensor that will turn off the charger when the battery begins to heat up at a rate of around one to two degrees Celsius per minute, indicating the battery is receiving too much current. [26]

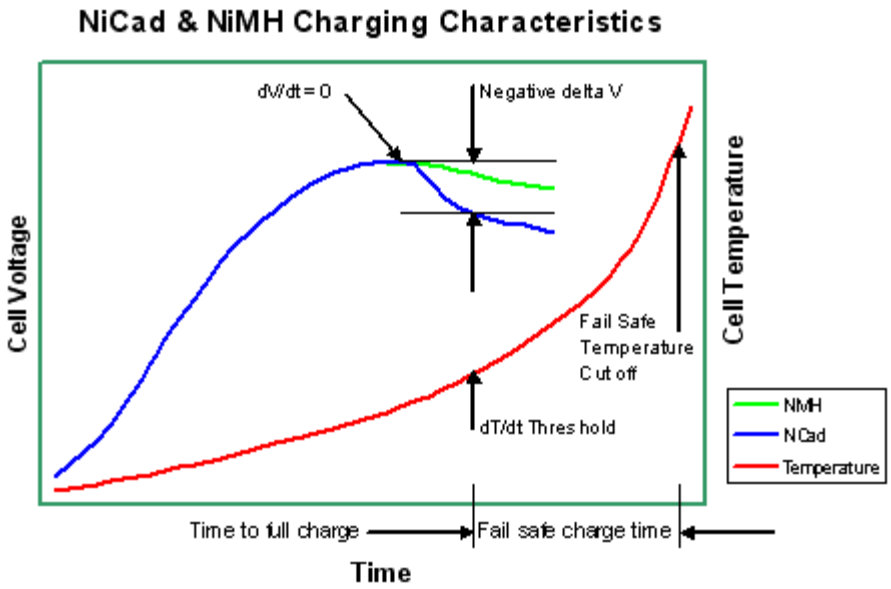


Figure 6: NiCad / NiMH Charging Characteristics

Although some users will avoid using NiMH batteries when they compare the battery to an alkaline battery of the same size because of the lower rated voltage, an advantage that the NiMH batteries have over standard Alkaline batteries, is that they will maintain a constant voltage. This means that even though a NiMH battery is rated to only give a voltage of 1.2V when most alkaline batteries are rated at 1.5V, it will not see the same effect of a gradual loss in voltage as with the alkaline batteries. [27]

The main disadvantage to the NiMH batteries is that it has to be fully discharged, and then charged to avoid losing capacity after a specific amount of time, which is usually around one month. This limits the types of applications that they can be used in, as devices that have to be on standby for a long period of time and may not even need the use the charge, would have to remove the battery for a full discharge and recharge of the battery for a full lifespan. Another disadvantage to the NiMH is that the batteries have the same sizes as standard alkaline batteries. This means that they are larger than many applications will allow. [26]

## LiPo

Lithium-ion Polymer batteries, most commonly known as LiPo batteries are used in many user electronic devices. Typically, lithium-ion polymer batteries are lightweight and can be in any shape, but usually are rectangular. The power capacity is higher than that of standard batteries, and can have a higher discharge rate which allows for a higher power output as well. Each cell of the lithium-ion polymer battery has a rated voltage of 3.7V, and are usually in groups of two to three cells per battery, depending on the intended use. [23]

The predecessor to lithium ion polymer batteries were lithium ion batteries. Unlike most charging batteries, it's negative electrode does not act as an oxide or dissolves. The negative electrode is made of a lithium ion and graphite, or another form of carbon. During the charge and discharge of the battery, the lithium ions move between the positive and the negative electrodes through a liquid electrolyte. Normal lithium metal first used when attempting to create a rechargeable battery. This design was scrapped when the unstable nature of the lithium metal became a safety concern, and they shifted to lithium ion designs, which were more stable in design when charging and discharging, but had a slightly lower energy density than that of the lithium metal battery design they initially were using. [23]

Lithium ion and lithium ion polymers are normally designed using one of two cell designs when made for small applications. The first design type was made in the early nineties, and utilize space by layering the cathode, anodes, and separators, or by having a long cathode and anode, which is them wound and flattened. This type of design is known as prismatic cell. The outside of the cell has to be harder than the other design to contain the compression of the layers of the cell. [31]

The second type of cell design is known as a pouch cell, and was designed in 1995. This design has conductive tabs welded to the electrode of the battery. This type of design is more used with the lithium ion polymer battery cells. The advantage to this design of the prismatic design is that it is able to achieve an efficiency of over ninety percent. This is done because the metal enclosure of most batteries is not used for the pouch cells. The two main disadvantages with this cell design is that is has a high possibility of swelling, and that it has no standardized size. The swelling of the battery is caused by the reactions in the battery causing gas, which can build up. While this may be a concern, the swelling usually only causes an increase in the size of the battery cell of about eight percent after five hundred cell cycles for small batteries, and as many as five thousand cell cycles for large batteries. To try to prevent the gases from building up, the first charge of the battery occurs with a bag on the side of the battery to capture the gas. After the gas is captured, the bag is removed and the battery is resealed. The size of the battery is completely decided by the manufacturer. This causes two batteries that produce the same power, to be a different size, and for a specific design to primary exist with one manufacturer. [31]

The lithium ion polymer batteries use a gel polymer inside both electrodes, and was developed to allow for the creation of very small batteries. The battery is encased with a plastic-aluminum and have a manufacturing process that allows for modifications to be easily made. This allows for these types of batteries to be ideal for cellular devices, as well other small user devices. [25]

An advantage to using LiPo batteries is that they are not hazardous to the environment. This is primarily seen in the use of disposing of the batteries. Many batteries use components that can be hazardous if thrown in the garbage or a landfill. If the battery is properly discharged, by discharging mostly over a circuit, and then creating a short by leaving it in saltwater for a day or two, all reactions will stop. This will prevent a fire hazard and make the battery safe to throw away. [25]

Another advantage to the LiPo battery cells is the lack of a memory effect on the battery. The memory effect is a consequence of many battery chemistries that cause the shortened lifespan of the battery. The idea behind the memory effect is that batteries will be typically be fully discharged before charging. This causes the charge and discharge cycle to be shortened. The memory effect is mostly fixable, except in the case of old batteries that need to be replaced. The effect is fixed by completely discharging the battery and fully charging the battery a few times. While the issue is fixable and should not be seen as a problem for batteries, the idea that a battery can lose capacity from improperly charging and discharging is ingrained in many users' minds. The fact that the LiPo batteries do not experience this type of effect, makes many users lean toward this battery type. [24]

The primary disadvantage to the lithium ion type batteries when compared to other types of batteries, are the safety concerns. One of the safety concerns is the risk that the battery may overheat and catch of fire. Most lithium batteries are equipped with a basic protection circuit to prevent short circuits or overcharging of the battery. However, if this becomes damaged, the overcharging or short circuit can cause the battery to produce more reactions that create heat. If the temperature of the battery becomes too high, the heat can start causing the reactions itself, and the heating will grow exponentially. When this happens, the battery can spontaneously combust, catching fire and destroying the device that it is attached to. This was most recently seen in the news as the cause for Samsung Note 7 phones to be exploding and forcing a recall of the product. This can also happen if the battery becomes punctures. Due to the highly reactive chemistry of the battery and the soft this outer cover, if the battery were to be punctured, a short circuit would be caused internally causing the overheating. Many of these problems can occur with no warning that something had occurred to the battery until it is too late. [21]

The protection circuits for the batteries are usually attached to the battery when sold, and is used to help prevent the above safety issues. The protection circuit is made using mosfet switches that detect when the current raising too high going in or out of the battery. If the current raises too high, a short circuit is assumed and the circuit shuts off current flow to and from the battery cell. The protection circuits

are also made to prevent the overcharging of a circuit, as in putting too much potential into the cells. This is prevented in some circuits by using operational amplifiers. The op-amps use feedback and when the potential gets too high on the feedback, the amplifier will saturate and current to the cell will stop flowing. [22]

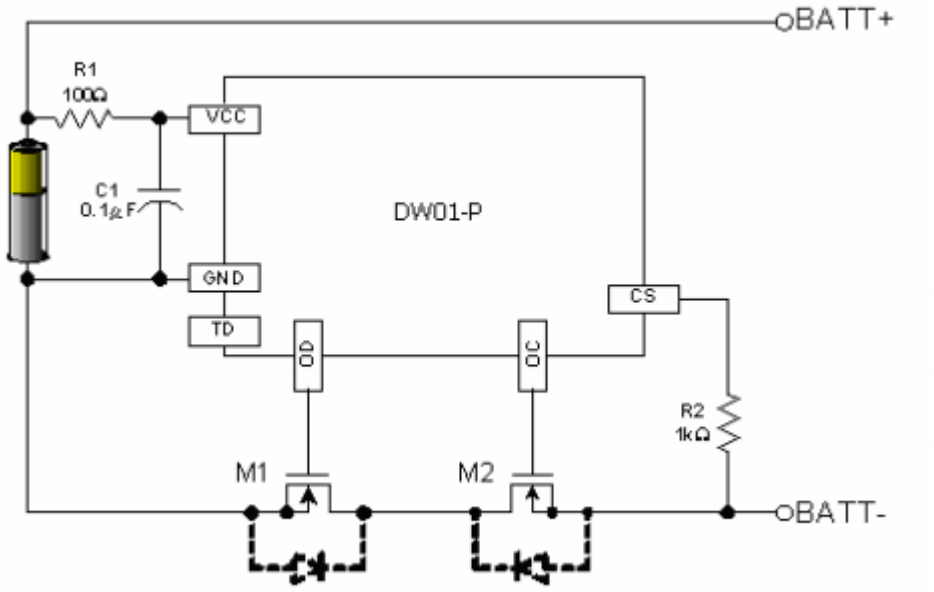


Figure 7:LiPo Protection Circuit Example

LiPo batteries charge using a system that allows for constant current and constant voltage. If charged using pulse charging or having a varying current or voltage can damage the battery. Another potential way to damage the battery is to charge the cells in parallel instead of in series. When the cells are placed in parallel, the charger will only be able to read the voltage of a single cell, which may charge at a different rate than the other cells, increasing the possibility of overcharging. Also when using parallel charging, the capacity of the cells are added together, causing a larger current to be used in the charging. The large current can cause the overheating of the cells. Chargers the work with LiPo batteries are also made to balance the voltage of each of the cells in the battery. This is done to ensure that the cells all discharge at the same rate, and so that the protection circuits can properly cut-off when all the cells of the battery are charged and not that a single cell is overcharged, and other cells are under-charged, with the former being a major safety issue. Charging for the batteries is made to be done slowly, with a rate of around one to two times the capacity of the battery, as opposed to the discharge rate typically being a maximum of twenty to fifty times the capacity. This is done to prevent overheating. Even with this precaution, some believe it is still a good precaution to charge the batteries in a fireproof container, so if the battery was to combust, then it would be completely contained already. [25]

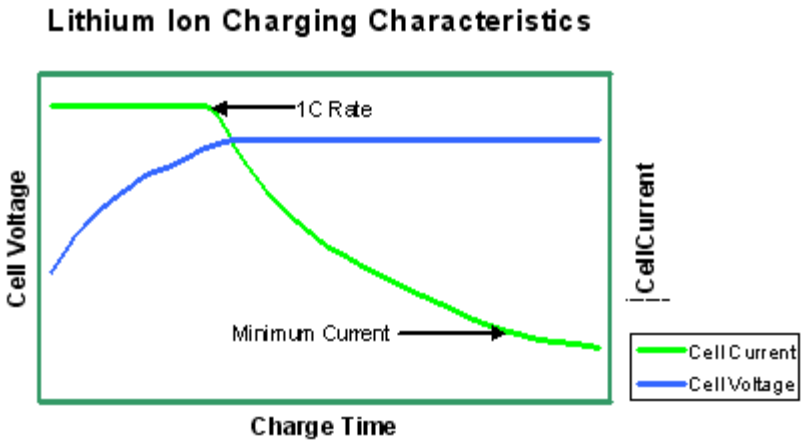


Figure 8: Li-Ion / LiPo Battery Charging Characteristics

| NiMH Vs LiPo | |
|---|---|
| Has Standardized Sizes | Non-Standard Sizes: Can be as small as manufacturer wants |
| Uses more Pulsed Charging Techniques | Uses Continuous Charging |
| Non-Constant Voltage during Charge | Maintains constant Voltage and Current to balance Cells |
| Harder, Safer Outer Shell | More volatile Chemistry, can combust if short |
| Uses Temperature sensor to stop current in case of a short | Uses Protection Circuit to prevent shorts |
| Must be fully discharged to maintain lifetime of the battery | Has no memory effect |

Table 1: LiPo Vs NiMH

The table above shows the comparisons of some of the aspects of the NiMH and LiPo batteries. While the NiMH is a much safer battery which is a thing to be considered with consumer devices, the size requirements of the device that is to be made is much stricter in the case of the customer request. The safety feature is also protected by the protection circuit of the battery which will cause no current

to flow if a short is discovered, as opposed to relying of the battery's temperature to determine if a short had occurred, which can be affected by other external temperatures as well. The battery is also protected by the casing of the device to prevent shorts caused by piercings of the battery pack itself

## Activator:

For the activator, a coin cell was chosen, primarily due to the sizing constraints of the device itself. With the device being off instead of standby, the lifetime of the battery was a factor that could be ignored, leading to the choosing of the CR1225 battery for the activator, which has a diameter of twelve and a half millimeters and a depth of two and a half millimeters.

## Defense:

### Battery 1: Hubsan Q4 Nan Proto-X

The Hubsan Q4 Nan Proto-X battery is produced by Hubsan for its quad-copter, the Hubsan Q4 Nano quadcopter with a charge time of 30min and flight time of 5 min when used in the copter. The battery is tested to have a maximum capacity current of 100mAH with a constant voltage of 3.7V. Built onto the battery is an overcharge protection circuit that will prevent too much current entering the battery, destroying the battery. The size of the battery is 20mm x 14mm x 6mm. This would take about half the of area in the Defender, leaving little room for the communication device, or the defense mechanism. If draining at full current, the capacity of the battery at two amps allows for a min time of use to only be three minutes.

### Battery 2: LiPo Battery Cell 3.7/110

The LiPo battery cell is a lightweight battery cell providing a constant voltage of 3.7V and max capacity of 110mAH. The size of the battery is 28mm x 12mm x 5.7mm. The battery contains a protection circuit similar to the previous battery discussed. The sizing of the battery is taken more in length than width allowing more space for the defense mechanism, despite the larger area overall. While running at a standard discharge rate of .2A, the battery will last about half an hour before needing charging.

### Battery 3: LiPo Battery Cell 3.7/40

This LiPo battery cell is lightweight, providing a constant voltage of 3.7V but with a max capacity of only 40mAH. The reduced capacity is due to the miniscule size of the battery. The size is only 20mm x 11mm x 4mm, fitting within the preferred depth of the device. The length of the battery is also shorter than previous batteries giving more room for other circuitry without taking space from the defense

mechanism. This battery is able to run for a maximum time of an hour, but provides a smaller current max with about 40mA compared to the 200mA that the other batteries provide.

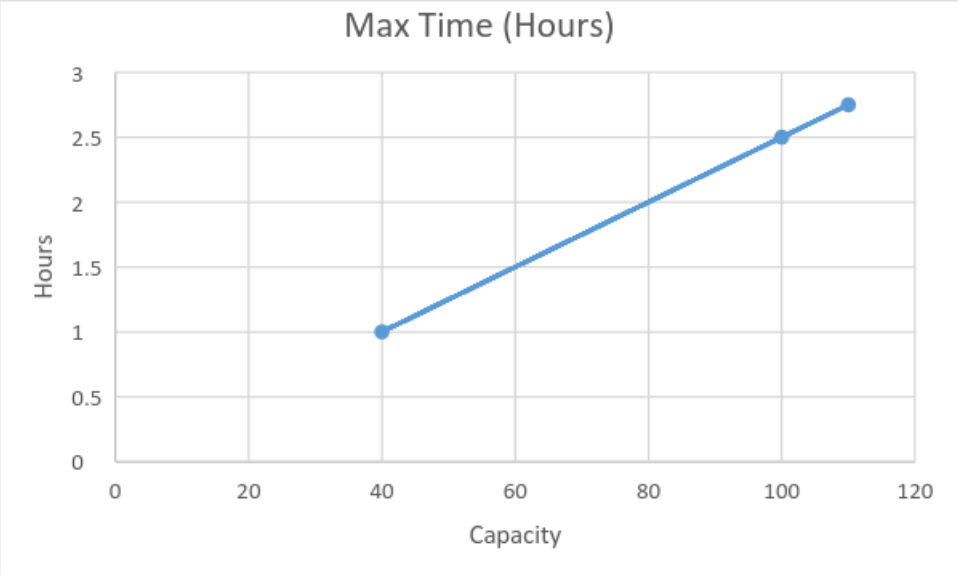


Figure 5: Capacity vs Time comparison

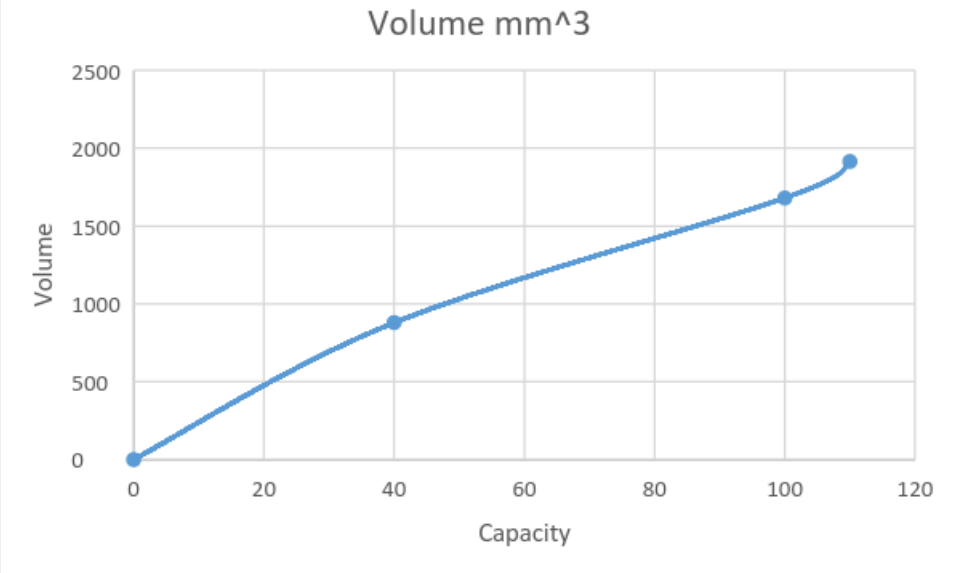


Figure 6: Capacity vs Volume comparison graph

Given all above batteries, the selection was made to use the LiPo with a capacity of 110mAh above the others. While the 40mAh battery was rated for a longer lifetime, the current draw is more limited and may not work for the application needed. If they are all set to have a current draw of 40mA then the 110mAh battery will be able to last for about three hours, making the comparison more equal. The 100mAh capacity battery did have a battery capacity compared to the volume that

the battery would take, but the difference was small enough to ignore because the 100mAh battery was more specialized for a specific use from the manufacturer and would need a difference charging circuit to be built onto the PCB than the other LiPo batteries that were reviewed and researched for the device.

## Buzzers:

The primary need to the speaker device will be in the second defensive device. For the project and testing purposes, the speaker will act as an allegory to the defense mechanism activating and can be used for the purpose of getting consumers used to the use of the device without having the actual mechanism. The device will require the buzzer to be heard from at least a distance of a foot and be able to not increase the size of the device, keeping the height less than eight millimeters, without hindering the sound pressure. The device also would need to be at a frequency that will alert the user and attacker, without being to the point of being so high, it may not be heard or being at a frequency that the consumer would not practice the use of the device, which could lead to a misfire, in the future use of the device. The two practical types of buzzers that can be within the size needed while still producing at a practical frequency are piezo-electric buzzers, and electro-magnetic buzzer.

### Piezoelectric buzzers

Piezo buzzers are electric devices that produce sound using the inverse of a concept that was first discussed in 1880 by Pierre and Jacques Curie. Their discovery was that electricity could be produced by applying pressure to certain types of materials. If an alternating current is applied to the material, the material with begin to stretch and compress. As this happens, the vibrations cause a sound, with the tonal frequency being dependent on the material and the size of the material. [20]

A common type of piezo buzzer is called a piezo transducer. The piezo transducer can operate with a DC voltage and contains an oscillator inside to cause the vibrations. The transducer is made by covering the piezo disk in a plastic coating with a hole on the top for the sound to propagate from. Many of the piezo type buzzers work in a range of three to twelve volts, rated at around six volts. Some piezo buzzers can work as high as two-hundred and twenty volts. The piezo buzzers are also made to be loud and can be used for sirens while other types of sirens are made lower in tone and not made to be heard from as far away. This is a great feature for alerting others, as would be needed for the device, but the hardware required for the type of sound pressure would need to be much larger than the allotted size of the device. [20]

One of the downsides to the piezo buzzer is that it produces a higher rated frequency for the size when compared to other types of buzzers. These high frequencies may not be considered idea for a consumer market, as a high frequency can be considered an annoyance if the high frequency is not required. The piezo buzzer also operates at a higher voltage that other types of buzzers. If the device is being run off batteries, it would require multiple cells to run, as most batteries have a rating of 1.2V to a max of 3.7, but the lowest the device can even begin to operate at with current technology is at 3V but six or more is usually preferred. [19]

The primary disadvantage that the piezo buzzer has to other types of buzzers is that it requires an oscillator to work on a DC voltage. This is also seen in other types of buzzers as well, but many of them have the wave generators built into the design of the buzzer. For the piezo to be smaller, it causes the need more hardware and more use of the battery, which will reduce the overall lifetime of the device. [20]

## Magnetic Buzzers

Another popular type of buzzer is a magnetic buzzer. The buzzer works by a small vibrating disk that is attracted to a magnetic field. When current runs through a coil in the buzzer, the field fluctuates causing the disk to vibrate as a sound producing frequency. Due to the use of magnetic fields, the device uses a smaller voltage than other buzzers, and the frequency at which it operates is lower. The current consumption is also much higher because the current going through the coil generates the opposing magnetic field to the magnets in the device to cause the fluctuations and vibrating of the disk. [19]

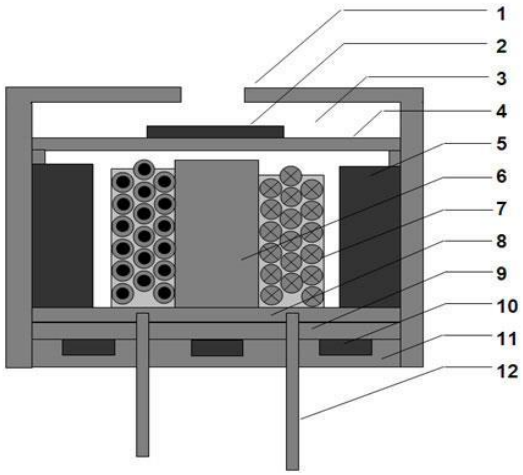


Figure 9: Magnetic design layout

The above figure is the design for a magnetic buzzer. In the figure, 1 represents the casing of the buzzer, 2 represents a weight that is placed on the vibrating disk and the vibrating disk is 4 on the diagram. Below the disks are two magnets, 5, and a coil wrapped around a pole, 7 and 6 respectively, which create the magnetic field that causes the disk to vibrate. [19]

One of the advantages to the magnetic buzzer is that the design of the indicator circuit has a build in driving circuit which will generate the frequency at which the current will change. The frequency is easily fixed on the design of the circuit. The transducer, on the other hand, uses external oscillations and are made to work at a wide variety of frequencies. The magnetic buzzers are also made smaller than other buzzers. Another advantage to the magnetic buzzers is that the frequency at which it will sound is at a lower frequency. This allows for a more preferred sound for a consumer if used in testing purposes, and will still be high enough to alert the attacker, confusing, and allowing for escape if needed in that situation. [19]

The disadvantage to using the magnetic buzzer is that it has a lower sound pressure level. This will make it not seem as loud to the human ear as other buzzers. The buzzers are normally tested for a distance of 10cm and are normally around 85dB at that distance, which is about as loud as standing ten meters away from a busy highway. The sound pressure drops 6dB every time the distance is doubled, so at a distance of one meter, it will be about as loud as a normal conversation at 61dB. The comparisons can be seen in the table below. At this level, the buzzer may not be as alerting if used with the primary self-defense mechanism. [19]

**Comparison of Different Sound Pressure Levels**

| | | |
|---|---|---|
| Jet Engine at 30m | 632 Pa | 150dB |
| Threshold of Pain | 63.2 Pa | 130dB |
| Hearing Damage | 20 Pa | 120dB |
| Jet at 100m | 6.322 Pa | 110-140 dB |
| Jack Hammer at 1m | 2 Pa | 100 dB |
| Traffic of Highway at 10m | 2x10^-1 Pa – 6.32x10*-1 Pa | 80-90 dB |
| Passenger car at 10m | 2x10^-2 Pa – 2x10^-1 | 60-80 dB |

| | | |
|---|---|---|
| Normal Conversation at 1m | 2x10^-3 Pa – 2x10^-2 | 40-60 dB |
| Very calm room | 2x10^-4 Pa – 6.32x10^-4 | 20-30 dB |
| Auditory threshold at 1kHz | 2x10^-5 Pa RMS | 0dB |

Table 2:Sound Pressure Level Comparison

Another disadvantage to using a magnetic buzzer is that the current draw of the buzzer is larger when compared to other buzzers. The overall lifetime of the device is then shortened, which can make the component less desirable for a consumer device.

| Piezo Buzzer Vs Magnetic Buzzer | | |
|---|---|---|
| Quality | Magnetic | Piezo |
| Frequency Range | Low (1-3kHz) | High (2-6kHz) |
| Size | Small (6-25mm) | Large (10-50mm) |
| Over-rating Voltage | Low (1.5-12V) | High (9-25V) |
| Sound Pressure | Low (70-90dB) | High (85-120dB |
| Current Draw | Low (35-60mA) | Low (5-20mA) |

Table 3:Buzzer Comparison

The table above compares a few of the qualities of the buzzers that were deemed to be important to the design and to the customer requirements. While the most ideal buzzer would use a smaller current to allow the device to last longer, the buzzer itself will not be in use for the whole lifetime of the device, rather only for a short burst amount of time. Excluding the current draw and sound pressure, the magnetic buzzer is proven to be more ideal for what is required for the device being made.

## Magnetic Buzzer Comparison:

### Mallory Sonalert Products Inc. Magnetic Buzzer

The magnetic buzzer manufactured by Mallory Sonalert Products Incorporated is able to be work with a three volt input with a current of at least thirty milli-amps. The buzzer is able to produce a sound at two point seven kilohertz which is at a high enough pitch to be heard and alert others, while being in a range that can be heard by most, as hearing high frequencies can deteriorate with age. The sound pressure of the device is eighty-two decibels at a ten centimeter range, which is just below the average range of the magnetic buzzers. Unlike most other magnetic buzzers that are being researched for use, this buzzer is through hole, which is easier to solder and attach to the PCB but this can typically cause the size to be slightly larger than others. The size of the buzzer is a nine millimeter diameter, with a height of five point seven millimeters. Another difference between this buzzer and the other buzzers that are being considered, is that the sound is propagated from the top of the buzzer, while the others are propagated on the sides.

### Soberton Inc. Magnetic Buzzer 2.7kHz

The Soberton Incorporated manufactured magnetic buzzer has a rated voltage value of three point six volts, and requires a current of 70mA to work. This is just under the voltage that will be given by a single celled battery, but is able to work in a range between two and four volts. The buzzer produces sound at 2.73kHz, and has a sound pressure of eighty-seven decibels. This is slightly higher than the average sound pressure level of magnetic buzzers which will allow it to seem louder at the same distance than other magnetic buzzers. The size of the buzzer is 7.5mmX7.5mm with a height of two point five millimeters. This height is well below the size that is allotted by the customer, so it will not hinder the design of the device.

### Soberton Inc. Magnetic Buzzer 4kHz

This Soberton Incorporated manufactured magnetic buzzer has a rated voltage of three volts with a range of two to four volts. The buzzer requires a current of ninety milliamps, which is the largest of the buzzers that are in consideration. The sound produced is at four kilohertz, which is more alternative than the other considered buzzers. This comes at the cost of a lower sound pressure, at only seventy decibels. At a distance of a meter, the pressure drops to forty-six to fifty decibels, as compared to the average at around sixty-one decibels. The size of the buzzer is four by four millimeters with a height of two millimeters.

## CUI Inc. Magnetic Buzzer

The CUI incorporated magnetic buzzer has a rated DC value of three volts with a range slightly larger than the other chips in consideration at two to five volts. The current required to run this buzzer is only thirty milliamps. The buzzer produces a sound a two point seven kilohertz with a max sound pressure of eighty decibels, just at the average level of the magnetic buzzers. The size of the buzzer is slightly larger than average at nine point seven by nine point seven millimeters with a height of five millimeters. A unique feature of this buzzer compared to the other considered buzzers, is that the soldering points are gold plated, which has a lower resistance and allows less power loss.

| Table of Speaker Comparisons | | | | |
|---|---|---|---|---|
| Buzzer | Drive Voltage | Frequency | Sound Pressure | Volume |
| Mallory | 3 V DC | 2.7 kHz | 82dB | 362.43mm^3 |
| Soberton 2.7kHz | 3.6V External Signal | 2.73 kHz | 87dB | 140.63mm^3 |
| Soberton 4 kHz | 3V External Signal | 4 kHz | 70dB | 32mm^3 |
| CUI | 3 V DC | 2.7 kHz | 80dB | 470.45mm^3 |

Table 4: Speaker Comparisons

When considering all of the buzzers, the most ideal is to use the Mallory buzzer. While both of the Soberton manufactured are smaller in size, they require an externally driven signal to produce to sound while the other buzzers are able to work with only a DC signal. The Mallory manufactured buzzer was then selected over the CUI manufactured buzzer, due to the smaller size and increased sound pressure while having the current draw and output sound frequency.

## Light Emitting Diodes:

Another component that will be used in the defensive device will be a light emitting diode. This will be used to show activation of the device has occurred. It will work congruently with the buzzer system described above. [18]

A light emitting diode works by the movement of electrons in the diode causing photons to be emitted. They can be used for screens, clocks, indication lights, and as a replacement to incandescent light bulbs for normal use. From the use of them in screens, televisions and computer monitors have been able to become very thin as compared to the box monitors and giant television sets that were being used only a decade ago. [18]

The diode that the LED is made from is one of the simplest forms of a semiconductor. They are created using a poor conductive material, and adding other elements to the material to create an excess or absence of electrons, that allows current flow in a single direction. For light emitting diodes, the typical type of material that is used for the poorly conducting material is aluminum gallium arsenide. When an excess number of electrons are created, the material is considered to be n type, as it has a more negative charge while and absence of electrons for equilibrium is called a p type material. A diode has both a single n type side to it and a p type side to it. For a diode to work, a certain voltage has to be reached between the two terminals of the diode before it will work. For analysis purposes, in a DC circuit, the diode is seen as a voltage source, opposing the driving source. [18]

The light that is emitted from the diodes is caused by the changing in the amount of energy that the electrons in the diode have. If the change in energy is great enough, the photon emitted will have a wavelength within the visible spectrum of the human eye. Most diodes are unable to do this as the base material used has a small change in energy levels, so the wavelength is too small to be visible. The bulbs that are used to contain the diode are used to direct the light in a single direction to concentrate all of the released photons, to make the light more visible and brighter. [18]

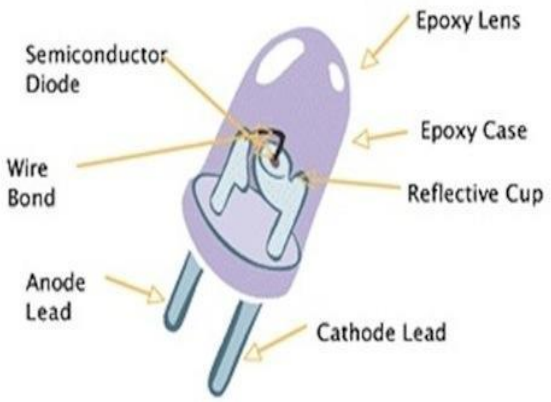


Figure 10: Layout of a typically LED

Due to the way the light emitting diodes produce light, they have advantages when compared to other light producing devices. A standard bulb that is used in many people's houses are made is a filament in the middle that creates light when current passes through it. This light is caused by the resistivity of the filament that causes the filament to heat up as it resists the current flow. On the other hand, Light emitting diodes do not create a lot of heat when being used, and are able to last much longer that a standard light bulb that will stop working if the filament inside the bulb breaks. The lifetime comparison of an LED to a normal light bulb is that is can last up to fifty-thousand times longer. [18]

The main disadvantage to a light emitting diode is that is costs more than other sources of light. The technology that creates the LEDs is complicated and needs the creation of the diodes, while other types of light bulbs are made by either putting a filament between two points and placing it inside a bulb, or by filling a tube with gas, that will reaction in the presence of voltage, and will begin to emit light. However, for uses outside of a normal light source, they have little disadvantages, and can be made to be put is very small devices, both emitting light and acting as a diode in the circuit. The only disadvantage to using a LED is that if it gets too hot for too long a period of time, then more electrons would be freed and the diode would no longer work as intended. [18]

## Relevant technologies for device 1:

Device 1 will mainly be comprised of a battery that is connected to multiple switches which are in parallel of each other which are then connected to the communication chip. This is done so that when only one switch is trigger, the communication chip can be activated. Ideally, the battery would last long enough for the signal to be sent for the possible activation of multiple device 2's that are paired with only a single device 1. This is only meant as a safeguard to prevent the device from being used in the wrong hands. In reality, that the battery being used

is not meant to drain at a rapid rate which would cause the chip to stay on for a longer period of time, so long as at least one of the switches are triggered. Also, the group wants to have the case be 3D printed for ease of manufacturability but at the same time wants the device to be sturdy enough to be able to survive a fall onto concrete from a height of 5 feet. This is the ideal case if the product were to go to market but for this project, a simple 3D printed case with a rubber coating will suffice.

## Push button switch:

Ideally, using a push button switch would be the most simplistic route to take during the design process. A push button switch operates by simply press the button to complete the circuit and if the button is not pressed, there is an open where the switch is located. Push button switches can vary in size from being as small as a fingernail to be as large as a start button for a power generator. Sometimes the buttons on the small scale push button switch are too small which then requires a mechanism to allow the user to use the button effectively. Size is a crucial part for both devices so have a button that is small enough to allow the circuit to be complete would be ideal but that is not always the case. Different push buttons are rated differently for different amounts of current and voltage. The chip that the group is using requires at least 10mA in order to be operational and switches that our group has looked into are rated to be from 1 to 50 mA which is in the operational range of the chip. The switch the group is looking into is 6mm by 6mm by 6mm which is within our design specifications for the project and since there will be two of them, it is ideal that the group reduces the size of the circuit as much as possible. [2]

Figure 11: PTS820 J20KP SMTR LFS push button switch

The picture above is the PTS820 J20KP SMTR LFS push button switch that seems to be one of the possible options for the switching mechanism in device 1. This particular push button has the dimensions of 2.0mm by 2.9mm by 4.4mm which is the ideal specifications for device 1 as it is small enough to fit inside of the key fob

like device. This push button has an operating force of 250 plus or minus 50 gF (1 gram-force corresponds to 0.00980665 Newtons and 1 Newton corresponds to about 0.22 pounds of force). The electrical restrictions for this switch are as follows: the maximum voltage is 12 VDC, the maximum current DC is 50 mA, and the operating temperature is from -40 C to 85 C.

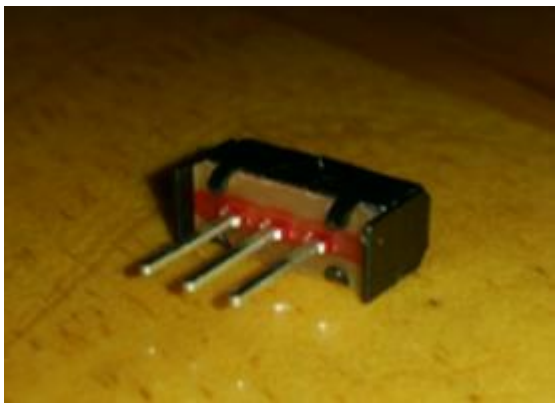

Figure 12: SPDT Slide Switch

The picture above is the Adafruit Accessories Breadboard Friendly SPDT Slide Switch which is also an option for device 1 and possibly device 2 due to its ideal size and reliable switching capabilities. Since this particular switch is breadboard friendly, it allows for easy testing and implementation. This switch's dimension is 11.60mm by 4.00mm by 12.1mm which may seem big for this project but a majority of the height is coming from the pins themselves and there is more breathing room to allow the switch to be longer. The electrical and environmental ratings are as follows: the switch is rated at 0.2A at 30 VDC with an operating temperature from –20 C to 70 C. The operating force needed to move the switch from the off to on position is 250 plus or minus 100 gF.

Figure 13: Standard tactile switch

The picture above is a standard tactile push button switch used in various switch applications and is an option for use in device 1 as the switching mechanism. The dimensions for this particular switch are 6.00mm by 6.00mm by 10.5mm which is an ideal size for this project but a concern may arise due to how wide the switch is as it may not fit the casing of the key fob like shape of device 1. the maximum current rating for this switch is 50mA while the maximum voltage is 24 VDC. The operating temperature range is from –25 C to 70C and the average operation force need to push the button is around 100 gF while it can withstand a maximum of 250 gF of pressure.

## Capacitive touch sensors:

Capacitive touch sensors have the ability to replace the existing mechanical switch that will be used for this project. A capacitive touch sensor works by when a person touches the contact surface, capacitor is formed which draws more current from the sensors. The sensor then measures the currents at each of the four corners of the sensor and the ratio of the currents compared to each other are used to determine the location of where the person touch the sensor. Another method for capacitive touch sensing is the projected capacitive method which has an X-Y grid of conductive material on the underside of the touchpad. When a person touches the touchpad, much like other methods, measure where a person touches by the current drawn on the circuit due to the person's finger creating a capacitor. Due to the nature of capacitive touch sensors, they can be completely customizable, meaning, a person can adjust how sensitive the pad can be so that a user could activate it by either have a finger touching the sensor or it can be activated by just having a finger near it. The only problem is that the power consumption would go up tremendously when the touch pad is activated along with having the touch pad being on standby mode at all times which will draw continuous power from the battery. Having both the capacitive touch sensor and the chip would draw too much power from the battery along with having the whole circuit design be too complex for what this group wants to achieve. [3]

The capacitive touch sensor that was researched was the CAP1296-1-AIA-TR capacitive touch sensor which operates in a similar fashion to how the track pad on a laptop keyboard operates. Its dimensions are 3mm by 3mm with a height that would be ideal for this project. The voltage necessary for the sensor to operate would is 5V while the current necessary would be 10 mA. The sensor has an operating temperature from -40 C to 125 C while the operating force need to trigger the device does not need to be determined due to how the sensor works.

## MOSFET switch:

Ideally, using a MOSFET as a switch would be the most beneficial to the project do to the fact that a transistor can be made at such a small size. Using a MOSFET as a switch is a simple circuit that can easily be implemented on a PCB with the only problem being that when dealing with transistor, a person has to weary about the manufacturing process of transistors. When dealing with the process of making a transistor, some of them may not work right away or they may not work after only one use and this can be a problem for the consumer. For instance, if they trigger the switch and nothing happens due to a faulty transistor, the person can be in major trouble. Another problem with MOSFET is that even though the actual transistor is small, the other components needed to complete the circuit are many times larger than it which requires a lot more space than the group needs.

## MOSFET switch diagram and explanation:

For a person to even consider using a MOSFET as a switch, they must understand how a MOSFET fundamentally works. The basic understanding of a N type MOSFET can be determined by analyzing its saturation region and its cut-off region. When a MOSFET is in the cut-off region, the MOSFET is turned off, meaning, there is no voltage going from the gate to the source, acting like an open switch. A MOSFET in the cut-off region has the threshold voltage greater than the gate-source voltage meaning that the drain current of MOSFET is zero and VOUT is equal to VDD. When a MOSFET is in the saturation region, VGS is greater than the threshold voltage of the MOSFET, acting like a closed switch. A MOSFET in the saturation region has the gate-source voltage greater than the threshold voltage meaning that the drain current has a value of VDD/RL and the output voltage is equal to the drain source-voltage. The MOSFET's mode is determined by the input voltage which is connected to the gate side of the MOSFET so that when the input voltage is greater than the threshold voltage, the MOSFET turns on and when it is lower, the MOSFET turns off. The characteristics of a N-type MOSFET starts off by when the input voltage is at its highest before the MOSFET starts breaking down. When the input voltage starts decreasing, the drain current slowly goes towards zero and ideally the input falls into range of the saturation region for ideal operation. Once the input voltage hits below the threshold voltage, the MOSFET goes into cut-off mode, essentially turning it off.

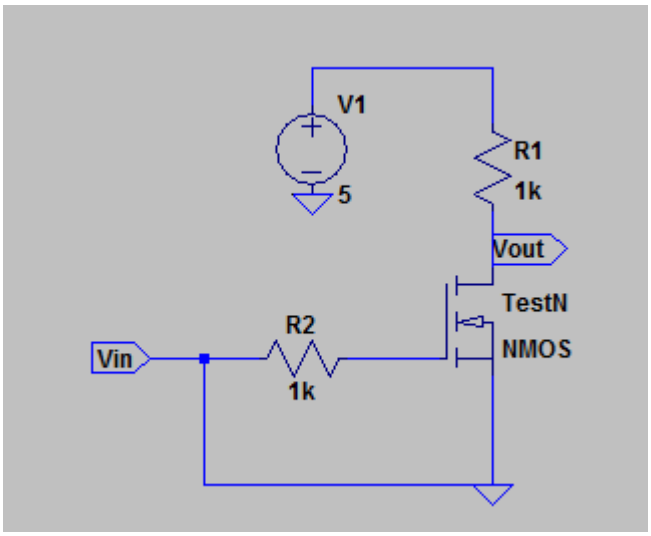


Figure 14: Standard circuit show a MOSFET in cutoff region

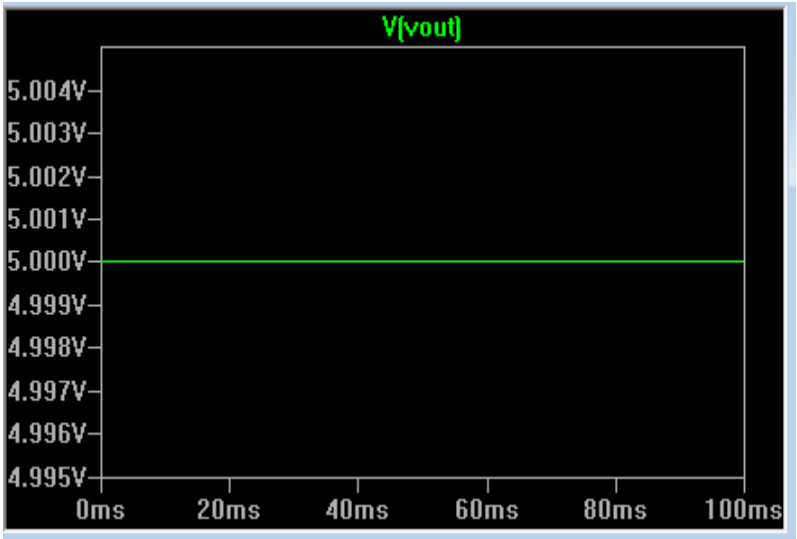


Figure 15: Simulation of MOSFET in cutoff region

The picture above is an example circuit with its simulation of the output voltage showing a MOSFET in the cut-off region and acting like an open switch. Vin in this picture is biased at the ground, which is 0 volts, force the gate-source voltage to be zero which results in the MOSFET to be off. Due to the MOSFET being off, the output voltage is then limited to the biasing voltage VDD.

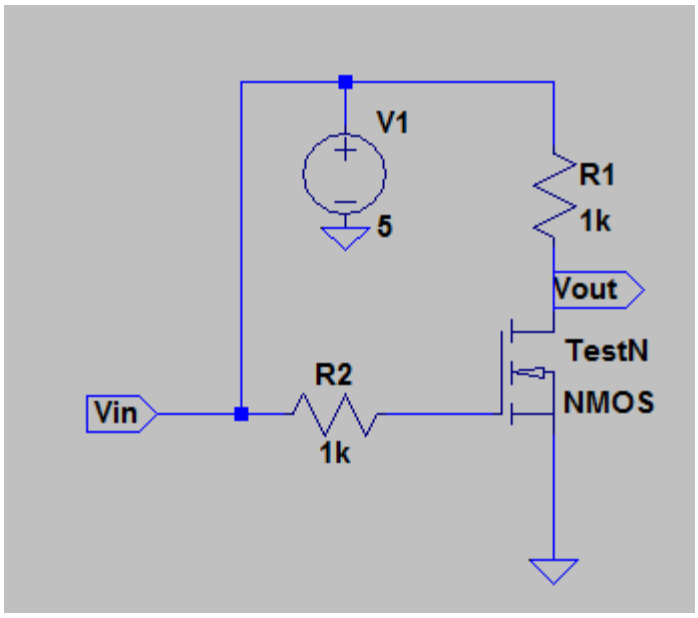


Figure 16: Example Circuit showing a MOSFET in the saturation region

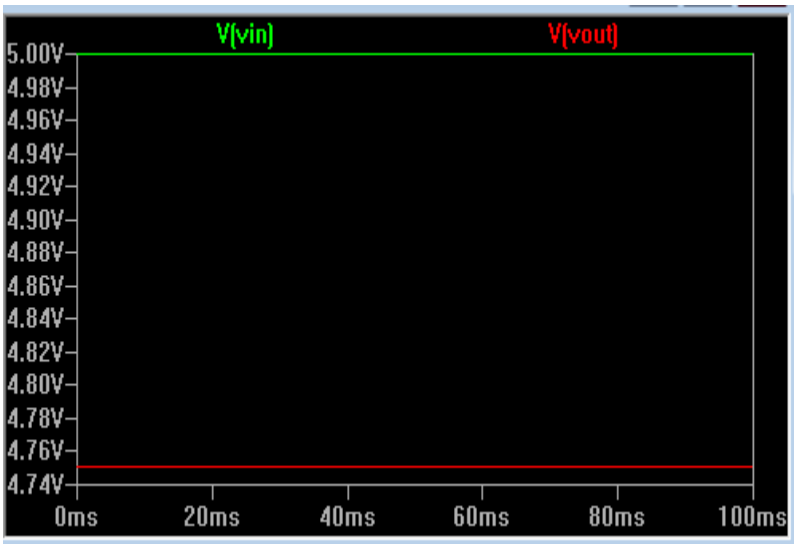


Figure 17: Simulation of MOSFET circuit in the saturation region

The picture above is an example circuit with its simulation showing a MOSFET in the saturation region and acting like a closed switch. Vin in this picture is biased to VDD so that the gate-source voltage on the MOSFET is greater than the threshold voltage which results in Vout being equal to VDD minus the voltage across the load resister R1.

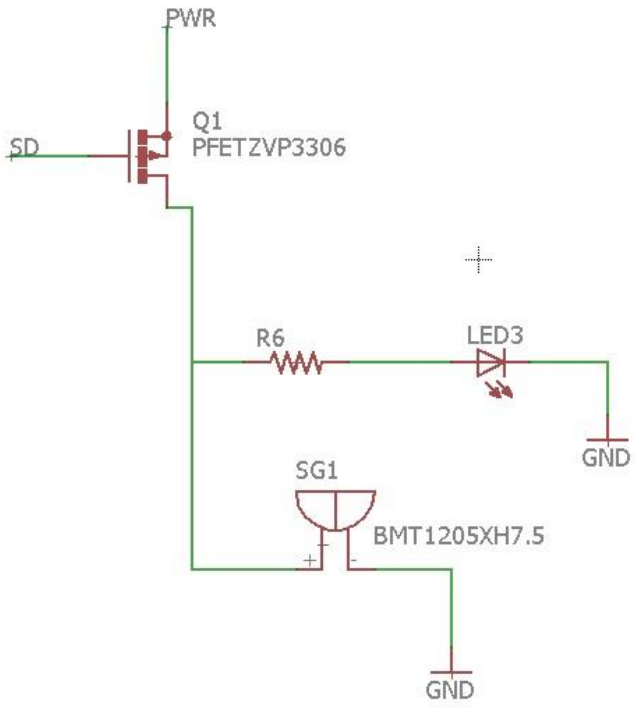


Figure 18: Self-defense circuit

The picture above illustrates the self-defense circuit that uses a N-type MOSFET functioning as a switch to turn on the buzzer and the LED. The idea behind it is that when an input comes into Vin, the gate-source voltage increases to beyond that of the threshold voltage, allowing the buzzer and the LED to turn on. Typically, in a circuit like this, the input voltage is a sinusoid, meaning that it has a variable input voltage based on the amplitude of the sinusoid as time goes on. When the amplitude is high enough, the lamp turns on and as the amplitude decreases, the lamp stays on until the amplitude drops below the threshold voltage. Any voltage that is below the threshold voltage, including negative values, would put the MOSFET into cut-off mode.

## Capacitive touch sensor using a MOSFET switch:

The basic ideal behind a capacitive touch sensor is that when a person touches the plate on the sensor, it creates a capacitive load which can be tracked by the sensor and the sensitivity can be adjusted by programing the sensor. The capacitive touch sensor alone cannot be used as a switch by itself as it only monitors the input from the plate but by connecting the output of the sensor to the input of the MOSFET switch, it is possible to create a circuit that allows the user to simply press the sensor to activate the switch. This would be the ideal set up for device 1 as it minimizes space and increases the functionality of the device. The main drawback is that by using the sensor, the MOSFET switch, and the communication chip all on one-coin cell battery, there will not be enough voltage

to go around to activate every piece of the circuit. For the communication chip to even turn on, there must be a minimum of 3 volts and a minimum current of 50mA and with the circuit set up with the capacitive touch sensor and the MOSFET switch, there will simply be not enough voltage to power the communication chip.

## Biometric switch:

Having a biometric switch on device one would be the ideal scenario. The person who would order the product would be the only person able to use it so that if the product were to get into the wrong hands, the potential user would not be able to use it do to the switch requiring the fingerprint of the original user. As great as it sounds, having something as complex as a biometric switch would not be beneficial for this group to achieve due to the fact that a fingerprint scanner would require too much power for the batteries we are using to handle. Also, this would add necessary complexity to the circuit along with increasing the size of device 1 to the point that it would not be beneficial for the consumer. Today's technology has simply not caught up to what the ideal goals are for having a biometric switch on something that is as small as this project. [6]

| | **Voltage (VDC)** | **Amps(milli)** | **Temperature range for operation (C)** | **Pressure need for operation (gram-force gF)** | **Size (mm, length*width*height)** | **Feasibility (yes or no)** |
|---|---|---|---|---|---|---|
| **Mini switch** | 12 | 50 | -40 to 85 | 250 +- 50 | 2.00*2.00*4.40 | Yes |
| **Sliding switch** | 30 | 200 @30 Volts | -20 to 70 | 250 +- 100 | 11.60*4.00*12.1 | No |
| **Tactile switch** | 24 | 50 | -25 to 70 | 100 to 250 | 6.00*6.00*10.5 | Yes |
| **MOSFET switch circuit with Capaciti ve** | 5V | 10mA | -40 to 125 | Determined by software | 3.00*3.00*relatively small | Yes |

| | | | | | | |
|---|---|---|---|---|---|---|
| **touch sensor** | | | | | | |
| **Biometric** | 24 | 200 | -5 to 50 | Finger print scanner | 38.1*69.34*54.102 | No |

Table 5:Switch Comparison

# Control Units

## Raspberry Pi

A raspberry pi is a small computer unit that runs on Linux. This can be used for highly complicated devices and commands and do intense calculations. These are typically using in programming for robotics or other highly computation heavy devices, although it can be used for sensor networks.

The downside for using these is that these are fully integrated devices and take up much more space than could possibly allotted for the final design. The devices that are being used also do not require the level of computation that would be provided by the raspberry pi devices. While great for total syncing up between the devices, the main use for the raspberry pi would be for a device that would replace the phone usage the in final iteration of the devices. [50]

## Arduino

An Arduino is an open source microcontroller that used a free software on the computer to write and possibly read code. The code is typically a simplified version of C++ which allows it to be easy to program and easy to use for beginners. Unlike most boards, the Arduino does not require a programming chip to load new code onto the board. One of the positives to using the Arduino is that they are made to be used for many different uses such as for artists, hobbyists, newbies and hackers, and can interest with many different devices, including GPS and a television. One of the downsides to Arduino chips and programming are not supported by many microcontrollers, only currently using Atmel AVR and SAM chips, with some ports to allow it to be used with a few other chips. The libraries for the Arduino are also very limited and the codes are inefficient, wasting memory and CPU cycles. This means excess time and power will be used for the chip, which can be detrimental for the lifetime of the devices. [51]


Figure 19: Example of Arduino Boards

## Texas Instruments Microcontroller

The most common microcontroller from Texas instruments is the MSP 430. These devices are easily accessible for student use and using base C programming to control. These microcontrollers are low power 16-bit devices with a large amount for peripherals and shields. To program these chips the user uses code composer studio, a free program provided by Texas Instruments. Some of the pros for the TI products is that they are relatively cheap with at most five dollars for a board or less than a dollar for just the chip. This would make them ideal for low cost devices. They also have an in-system debugging interface within code composer studio which make the device very easy to test and change the code on the fly. Some of the disadvantages for the TI microcontrollers is that they there are harder to use for beginners and use a power of 3.3V which would require to step down with most batteries. [52]

Figure 20: Example of a Texas Instruments Board

## Nordic Microcontrollers

Microcontrollers from Nordic are unique in that they also have wireless capabilities fully integrated onto the board along with the basic microcontroller functions. The CPUs are 32-bit ARM cortexes with 256kB of memory. The microcontrollers are designed to be used in very small devices such as wearable devices and RF tags. The primary advantage to using a Nordic microcontroller device is that the Bluetooth wireless is built into the chip so the device does not require additional hardware for wireless capabilities. The microcontroller supports low power Bluetooth protocols. The chip also has a flexible power management, working in a range of power compared to a specific voltage as the other microcontrollers require. The disadvantage to the chip is that the primary way of programming the chip is through ARM, an assembly language derived from MIPS, as opposed to a high level language such as C or Python. It can be configured to be programmed with Arduino code, but this will only work in a wired connection to programming, requiring the ports for programming be built on the PCB. [53]

Microcontroller Comparison Table:

| Chip | Memory | Programming Language | Power: | CPU bits |
|---|---|---|---|---|
| **Arduino** | Uno: 32kB<br>Mega: 256kB<br>Due: 512kB | C++ | Uno:5V 20-50mA<br>Mega:5V 20-50mA<br>Due:3.3V 130-800mA | Uno:8 Bit<br>Mega: 8 Bit<br>Due: 32 Bit |
| **TI MSP430** | 8kB Ram 116k ROM | C | 3.3V 200uA-6mA | 16 Bit |
| **Nordic** | 256kB Flash 32kB Ram | ARM | 3-3.6V 10mA | 32 Bit |

Table 6:Control Unit Comparison

The device chosen for the device is the Nordic microcontroller. Although the controller programming is more complicated, using an assembly language, the chip includes wireless capabilities which helps keep to the size constraint of the devices that will use the chip.

## 3D printing:

Even though 3D printing technology is not part of the project exclusively, is it still a good thing to know how it works in reaction to how it affects the electronics parts inside the completed model and whether or not it the electronics inside can survive a small. It is also important to know what kind of limitation the group has with 3D printing technology in terms of size, shape, material, and cost as all of this needs to factor into the final project design/cost. For this project, the group will be using ABS (Acrylonitrile Butadiene Styrene) plastic as the printing material do to its strength, flexibility, and machinability and temperature resistance. ABS has a standard impact strength of 5.7 ft-lbs/in which is a lot larger than the 1.8 ft-lbs/in of the PLA plastic. This means that the ABS should be able to survive a fall from a far greater height than that of the PLA plastic. Due to its cheap cost and widespread availability, ABS is the plastic of choice when it comes to simple parts that need to be engineered for cheap. With 3D printing technology, the group can easy alter existing schematics that will allow the group to house the PCB inside the casing.

## ABS:

ABS or acrylonitrile butadiene styrene is one of the many plastics used in the manufacturing of any small-scale product that needs to be molded. ABS plastic is a thermoplastic, meaning, it becomes a liquid at a certain temperature at around 105 C, making it ideal for molding. Another characteristic is that thermoplastics can be heated to their melting-point, cooled, and re-heated again without causing significant molecular damage. Because of its property of being able resist damage from heating and cooling, ABS plastic is perfect for recycling which allows for cheaper production because most of the ABS plastic that is put onto market is old ABS that has been recycled. Due to its cheap manufacturing cost and availability, it is a widely-used product that has an application in several different industries. For example, the popular kids building blocks toy, LEGOS, uses ABS plastic to mass produce their blocks as all the company must do it put liquid ABS plastic in the mold of whatever block they want and it is ready to go after it has been cooled. Another property of ABS plastic is that is resistant to physical damage, meaning, it can resist repeat impacts and not receive much physical damage. This makes it great in applications that requires a lot of human interaction. For example, the keys on a keyboard are made of ABS plastic due to its properties of being resistant to physical impacts. At around $1.50 per pound, ABS plastic is an ideal plastic for this group due to its cheap cost and capabilities for 3D printing.

## PLA:

PLA or polylactic acid is a plant based plastic that is the environmentally friendly alternative to ABS plastic. Just like ABS plastic, PLA is a thermoplastic, meaning, it can be easily molded at high temperatures and can be heated and cooled again several times before any real molecular damage occurs. This also means that it is great for manufacturing and recycling but it does have a drawback, at high temperatures, PLA starts to become soluble in water. If the plastic has any bit of moisture on it when it goes through the 3D printer, then it will start to deform and lose coloration. A strength that PLA plastic has over ABS plastic is that during the 3D printing process, PLA becomes more of a liquid when heated which allows more precision when printing products with sharp corners. ABS plastic requires a heat plate as the printing surface because ABS plastic tends to curl if it touches a cooler surface but PLA plastic does not necessarily require the heat plate but it will curl from time to time. A draw back to using PLA over ABS is due to its melting point temperature as it its possible for PLA to deform on a hot day.

Comparison table of ABS and PLA plastic:

| Plastic | Melt Temperature(C) | Molding Temperature (C) | Heat deflection Temperature (C) | Tensile strength (PSI) | Flexural Strength(PSI) | Price ($US dollars) |
|---|---|---|---|---|---|---|
| **ABS (acrylonitrile butadiene styrene)** | 105 | 204-238 | 98 | 6600 | 10800 | $25/kg |
| **PLA (polylactic acid)** | 157-170 | 178-240 | 49-52 | 8,840-9,500 | 6,950-16,000 | $25/kg |

Table 7: Printing Material

## Microcontrollers:

For this groups project, the nRF51822 chip will be used for the communication of device 1 and device 2. It already contains a microprocessor along with the Bluetooth chip need for this project. A microcontroller, essentially, is a mini sized computer that contains a central processing unit, random access memory, read only memory, input and output ports, timers and counters, interrupt controls, analog to digital converters, digital analog converters, serial interfacing ports, and oscillatory circuits. Microcontrollers are used in very single aspect of technology that the modern person uses in their everyday life. For example, a smart phone contains not only microcontrollers but it contains a Bluetooth chip, an antenna, a fingerprint scanner, and a lot more other components. Even smaller products such as smart watches or even a calculator all contain in some shape or form a microcontroller that processes the users input in order the generate the proper output for the user. The chip allows the group to send a send an analog signal from device 1 to device 2 where it is converted into a digital signal that eventually activates the defense mechanism in device 2.

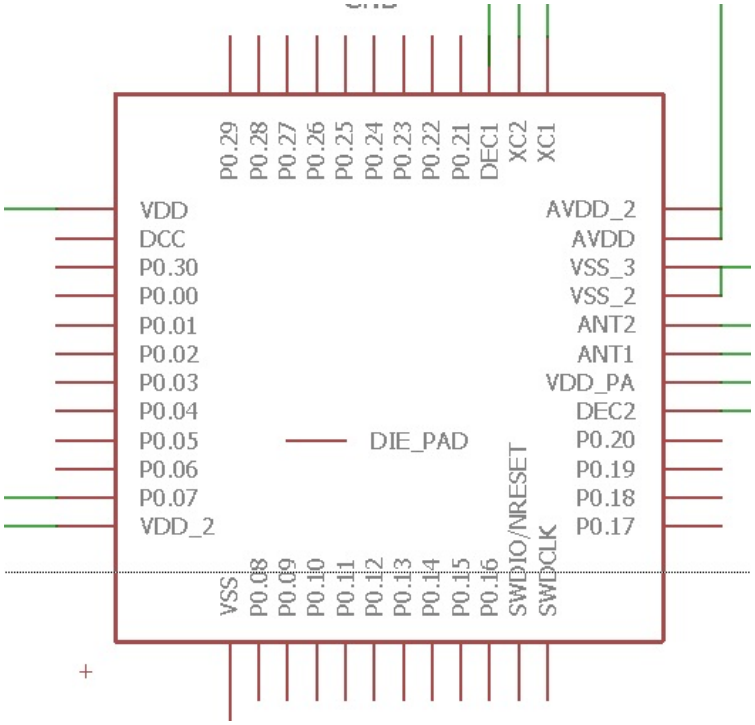


Figure 21: Chip Schematic

The picture above is the nRF51822 chip represented in the software program Eagle. Eagle is a program that allows the user to build a circuit that will later be implemented onto a PCB. All of the components that were listed that is inside a microcontroller is inside the chip that this group is using.

## CPU:

The central processing unit or CPU of the microcontroller is essentially the brains. The CPU's main function to take all the inputted data by the user and convert it into something that the user can work with. The CPU does this by using its internal memory, registers, and the memory located on the microprocessor. The CPU itself is also made up of a bunch of different components such as an analog to digital converter, random access memory, read only memory, timers, etc.

## RAM and ROM:

Random access memory or RAM works in a similar way to how short term memory operates in the human brain. Short term memory is the way the human brain processes new information and stores it which can be accessed at any time so long as it is continuously updated with the same information. After the brain processes, enough of the same information that was consistently put into short term memory, the brain puts the information into long term memory for later use.

RAM is mainly used for the newly inputted information and is never saved onto it but if the RAM does fill up, it puts into onto the hard drive (long term memory) to be accessed later. When the computer turns off, all the data that was in RAM gets wiped but the data in the hard drive does not so when the computer boots back up again, some of the information in the hard drive may be sent to the RAM. Read only memory, or ROM, works by being programmed only once right after the chip is being manufactured as nothing can be written to it, only read from it. The main function of ROM in a computer, for example, is to contain the necessary code for the boot up processes. This means that data in ROM is not lost when no power is connected to it which is different from RAM.

## Analog to Digital/ Digital to Analog converter:

Since the project this group is working on deals with the transmission of signals from device 1 to device 2 to the phone application, it is important to give back ground information on what happens. The components that make up the microcontroller consists of a CPU which house an ADC and DAC (Analog to digital converter and Digital to analog converter, respectively). The analog digital converter is essential to signal processing as it converts any analog signal, whether it be from light, a person's voice, or from a signal generator. By converting the analog signal into a digital signal, it allows the CPU to decipher the input signal in a way that it can understand it, typically into ones and zeros. The digital to analog converter works in the opposite way. Once the CPU runs through a line of code that requires it to send a signal to another device, the CPU runs it through a digital to analog converter so that way the signal can be sent over-the-air. This allows the signal that was generated by the microprocessor to be picked up by the other device and thus continuing they cycle.

## Timers/ Clocks:

The timers and counters essentially act as the clock for the microcontroller. The clock works by regulating the signal in a way that the CPU can understand at what time during the clock the program needs to execute on. Clocks and timers can control the brightness of an LED, for example, or even how many times an LED blinks per second. In addition to having clocks/ timers, all microcontrollers have a Quartz Crystal oscillator. The oscillator acts as a frequency regulator that allows the CPU to operate at a consistent frequency which determines the number of operations the CPU can handle per second. Every crystal is cut uniquely, meaning, every crystal has a different frequency that it can generate depending on the way it was cut along with how it is set up in a circuit. A typical quartz crystal for a CPU generates a frequency from one megahertz to 50 megahertz, depending on the model of microcontroller.

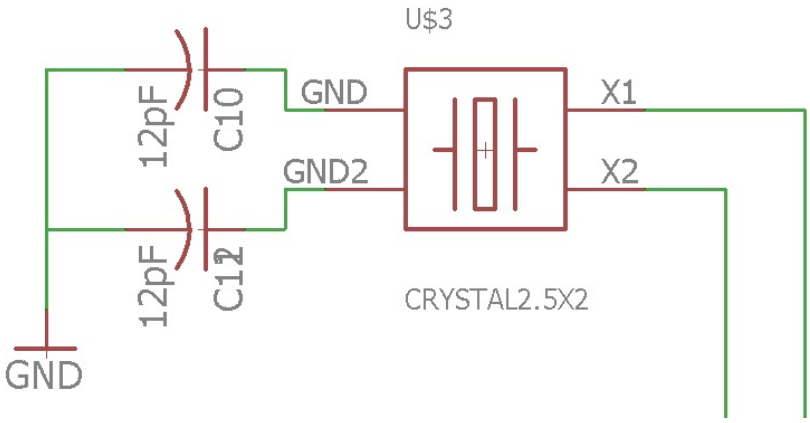


Figure 22: Example Crystal Circuit

The above picture represents a typical sent up for a quartz crystal oscillator. When the crystal in connected to the oscillator pins along with the two capacitors, its generates continuous square wave pulses which acts as the master clock for the CPU. This regulates how many instructions the CPU can operate per second.

### Other components of the microcontroller:

The rest of the components inside a microcontroller are all necessary for the function of it. The input and output ports of the microcontroller allow the user to program it while the output ports are typically lined up with an LED to show that the program is working. The interrupt controller is also another powerful tool for the user. The interrupt controller allows the user to program what is call an interrupt service routine (ISR) which allows the user to interrupt the CPU at any time during its running of code. When a CPU is interrupt, it stops everything that its doing, goes to wear the interrupt happened and executes that code, then starts up the original code again. Once a person is done programming the microcontroller, they have the option of soldering off the pins that allow programming. What this does is prevent any further programming of the microcontroller, at least from those pins. A downside to soldering off the pins is that if any part of the program goes wrong due to an unforeseen input then a person cannot go back and fix it.

## Bluetooth:

Bluetooth is the global communication standard that can connect devices together wirelessly over a certain distance. Bluetooth started out in 1994 when Ericsson, a telecommunications company in Sweden, came up with the idea to replace the RS-232 cables with a wireless RF based alternative. When Intel and Nokia decided to get into the business as well, they came together in Sweden to create a Special Interest Group(SIG) in 1998. A year later, the first version of the technology was created by the SIG consisting of Ericsson, Intel, Nokia, Toshiba, and IBM. Ever

since Bluetooth was implemented majorly in the 2000s, millions of different technologies now include Bluetooth technology in them. A revolutionary idea due to low cost, low power, and easy to use, Bluetooth has taken over the market and put itself in almost everything. The way it works is that Bluetooth devices use radio waves to connect to the other device, instead of wires and cables. These devices have a small chip with Bluetooth software that allows the products to connect, or pair, between the 2 chips. This communication between the 2 chips happen over a short range, less than 10m, ad-hoc networks, called piconets. When the connection is established, it then undergoes a master-slave system, where one device acts as the master and all other devices connected to it act as slaves. A total of 8 devices can be connected at once, with 1 master and 7 slaves. The most popular types of Bluetooth are the Bluetooth basic rate/enhanced data rate(BR/EDR) and Bluetooth Smart. Smart differs from BR/EDR in that not only does it take a lower power consumption, it also takes less channels to communicate through, where Smart has about 40 channels of radio waves and BR/EDR has about 80 channels, allowing Smart to have a larger field to work with. Some BR/EDR devices can be found in speakers and headsets, whereas Smart can be found in fit bands and beacons. While generally slower than Wi-Fi, Bluetooth complements it by having the larger devices, such as computers, connected over Wi-Fi and the smaller devices, like a mouse and keyboard, connected over Bluetooth. Figure 6 shows a picture of a common Bluetooth chip. [13]

Figure 23: Example of a Bluetooth Chip

Bluetooth Low Energy (LE), released in 2010 as part of version 4.0 of the Bluetooth standard, is a communications mode that provides much greater battery life for compatible devices not only by reducing the average current drawn, but also by reducing the peak current, allowing for operation to continue as the battery is more deeply discharged and the maximum output current drops. Standard BR/EDR

devices typically require relatively large batteries and frequent charging, while LE devices may be efficiently powered by coin cells such as the CR1225.

These energy savings were achieved by a largely redesigned wireless stack, casting off any functionalities required for the continuous transmission of data in favor of short messages sent infrequently. Peripheral devices spend most of their time in an off state, drawing only enough current to switch on quickly at an external trigger. In support of this, three dedicated advertising channels are used to establish connections in less than 3 ms, compared to the approximately 20 ms required by BR/EDR to scan its 32 paging and inquiry channels. Additionally, once connections have been established, LE devices do not require the continuous polling used by BR/EDR. The packet size is also reduced from 1021 bytes to 27 bytes, reducing buffer sizes (and thus memory power consumption) and the need to spend power recalibrating the transmitting radio due to heating effects. [37]

## GPS Tracking:

Global Positioning System(GPS) is a US satellite-based navigational system of about 24 satellites placed in orbit made to provide positioning, navigation, and timing. Initially built for militaristic purposes, this changed in the 1980s, where it become used more for civilian purposes for 24-hour access. GPS is a free service available to everyone with no subscription fees and doesn't need an account to work. The signals broadcast messages at 50 bits per second and operate at 2 frequencies called L1 and L2. L1 operates around 1575 MHz and L2 operates around 1227 MHz. Each transmission lasts for about 30 seconds and carries 1500 bits of encrypted data. GPS is broken down into 3 segments: space, control, and user segments. [12]

### Space Segment

The space segment works with the 24 satellites to transmit one-way signals to users to get the satellite's position as well as time. These satellites travel at an altitude of about 20Mm, are in 6 equally spaced orbital planes, and circle the Earth about 2 times a day. Each plane contains 4 slots that allows users to view at least 4 satellites at almost any point in the world. In order to work optimally, US Air Force added another 7 satellites to make sure that if a satellite were to go down, 1 of the replacements can take its place. In 2011, 3 more satellites were added to make 27 satellites now revolve around the world to improve efficiency. [34]

### Control Segment

The control segment consists of worldwide monitor and control stations to maintain the satellites within their proper orbit. Currently the segment includes a master control station located at Schriever Air Force Base in Colorado Springs, Colorado,

a secondary master station located at Vandenberg Air Force Base in Lompoc, California, 11 command and control antennas, and 15 monitoring sites. The master station at Colorado works with the US Air Force 2nd Space Operations Squadron (2SOPS) perform primary control functions. It generates and uploads navigation messages and maintains the satellite constellation. It receives navigation messages from the monitor stations and uses the information to compute the locations of the satellites in space, then uploads said data into the satellites. The master control station repositions satellites in the event that one of the satellites goes down. The monitor stations job is to monitor the satellites and relay their positions to the master control station. The antennas purpose is to communicate with the satellites for command and control purposes and normal command transmissions to the satellites. [35]

## User Segment

The user segment consists of the users and devices that receive these signals from the satellites and calculates its position and time. Any navigation solution provided by the receiver is based on its distance to a set of satellites, calculating propagation time of incoming signals that travel at the speed of light. The devices can be used for multiple purposes, whether it be for agricultural and surveying purposes, to the more well-known ones such as road and aviation purposes. Military purposes mainly use GPS for navigation, reconnaissance, and missile guidance, whereas civilians use it for surveying, navigation, and mapping and timing. Figure 5 shows a picture of this entire process starting at the space segment. [36]

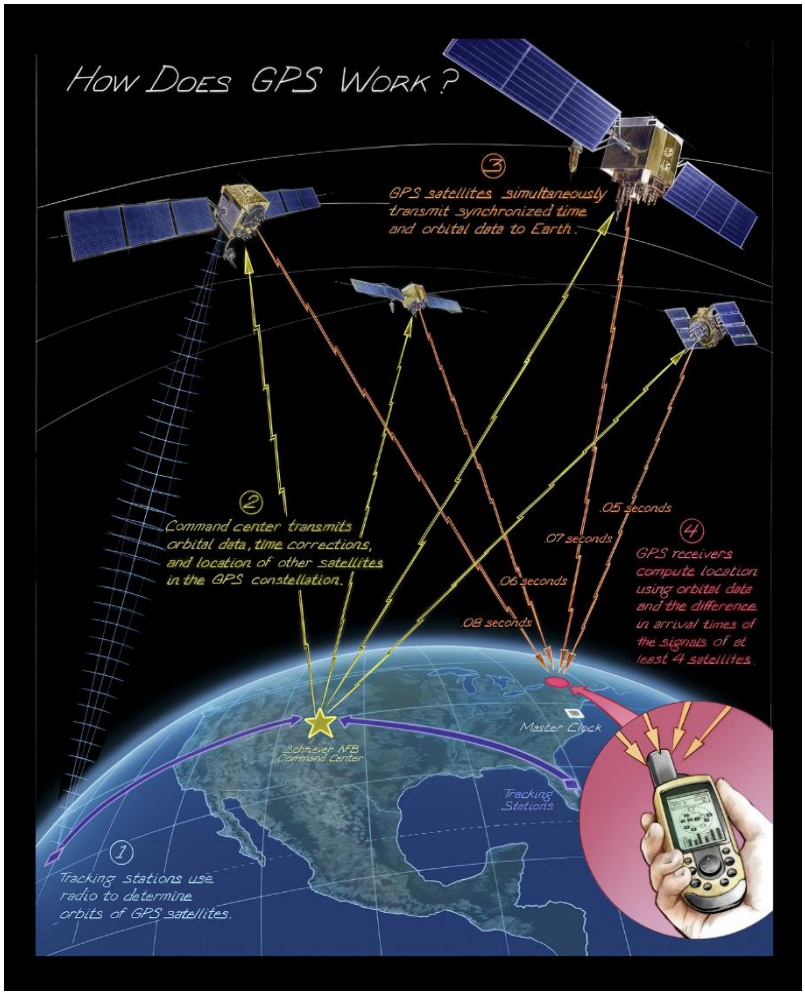


Figure 24: GPS Satellite Position

Also with the GPS is the augmentations, which is a method that provides any improvement to the positioning, navigation, and timing through the integration of external information into the calculation process not a part of the GPS. Some augmentation systems that can be found can be seen below.

## Nationwide Differential System

This system involves broadcasting correction signals on marine radio beacon frequencies of about 283.5 - 325.0 kHz with a range of 10 - 250 nautical miles to improve accuracy in GPS positions to users on the US waterways. Operated by the US Coast Guard Navigation Center, it has 1 control center and 46 remote broadcast sites, providing service to the Great Lakes, Hawaii, Alaska, and parts of the Mississippi River. These corrections are based on the North American Datum 83(NAD83) position of the reference station antenna. A geodetic datum is the coordinate system used to locate precise locations on the Earth. Since the Earth is curved, there needs to be an accommodation of the flat and curved views of the

Earth. By modeling the Earth as an ellipse, and taking measurements and estimations, a geodetic datum is made. This differential system is now in a steady decline of use due to lack of carriage requirement, technological advancement in GPS, and a limited availability of DGPS receivers. To rectify this, the Federal Register Notice was made to decrease the number of differential GPS sites across the country, but keeping the major sites up and running. [11]

## Wide Area Augmentation System

This system involves providing aircraft navigation across North America. Operated by the Federal Aviation Administration, this augmentation system takes over US National Airspace System due to not having horizontal and vertical navigation for approach operations. Due to this, this augmentation system is able to cover most of the National Airspace System. There are 38 WAAS reference stations, whose main job is to monitor the GPS and determine position errors. There are also 3 master stations and alternate master stations, who collect the information sent from the reference stations and create augmentation messages. These messages contain information that allow the GPS receivers to correct errors, thus improving the accuracy of their findings. These messages are then sent to uplink stations to be transmitted to navigation payloads on Geostationary communication satellites. The payloads then broadcast the message to the receivers and process the information to estimate position. Benefits of using this augmentation system include simplified equipment on board aircrafts, more direct flight paths, reducing broadcast signal accuracy from 100m to only 7m, and reduced cost of payment for old ground based navigational aids. [10]

## International GNSS Service

This system involves providing the highest quality data as the standard for the global navigation satellite systems (GNSS) in support of earth science research, education, and other applications that benefit society. The mission of the IGS is to provide the highest quality GNSS data, products, and services in support of the terrestrial reference frame and other applications that benefit the scientific community and society. The foundation of the service is a global network of over 400 continuously operating geodetic quality stations. In addition, Station data is archived at 4 IGS Global Data Centers and multiple Regional Data Centers. Applications of the IGS include scientific testing, geophysical monitoring, hazard detection and warning, time synchronization, imagery control and other public-benefit applications. [9]

### Global Differential GPS

This system involves providing real time support for NASA support of NASA's demanding terrestrial, airborne, and space-borne operations. In association with NASA, it comes as a highly accurate GNSS system. It tracks the GNSS civil signals on the L1, L2, and L5 frequencies. It is run by the Jet Propulsion Laboratory (JPL), a division of the California Institute of Technology, who manages the Lab for NASA. The main point of the GDGPS tracking network is a JPL-owned and operated network of 75+ geodetic-quality, triple frequency receivers, distributed globally. More real-time sites are contributed by US and international partner organizations. On average, at any given time each GPS satellite is observed, on average, by 25 ground sites. Driven by a powerful software set in C++, developed completely in-house at JPL, the software evolved from one of the world's leading GPS data processing and analysis software packages, JPL's GIPSY-OASIS and its real-time version Real Time GIPSY (RTG). Applications of this system include precise real-time positioning and orbit determination, real-time environmental monitoring, GPS performance monitoring and situational assessment, and more. [8]

## Three-Tier Web Applications

Most multi-user sites in the World Wide Web depend on a three tier architecture. The front-end tier consists of presented content transmitted encoded in, the display rules for the content’s presentation, and any locally interactive behavior proved by interpreted scripting, all downloaded by the user’s browser to render and execute on their local device. The middle tier contains the internet-facing web server and the web application proper, and many combinations of server and application languages are available for use. The use of a web server as a middle tier abstracts away the need to update client software as new functionality is added to the application and allows organizations to keep the server side source code private and improve security by hiding the interface details between the middle tier and the back-end database management system (DMBS). The back-end responds to queries made by the middle tier for application data, protecting data integrity from attacks made on the forward tiers. In smaller deployments, the DBMS may run on the same server as the web application, but separating it into its own tier allows for scalability by being able to relocate data storage to specially optimized hardware, and in larger deployments typically involves clustered load-balancing. The general structure of a three-tier application is shown in the figure below.

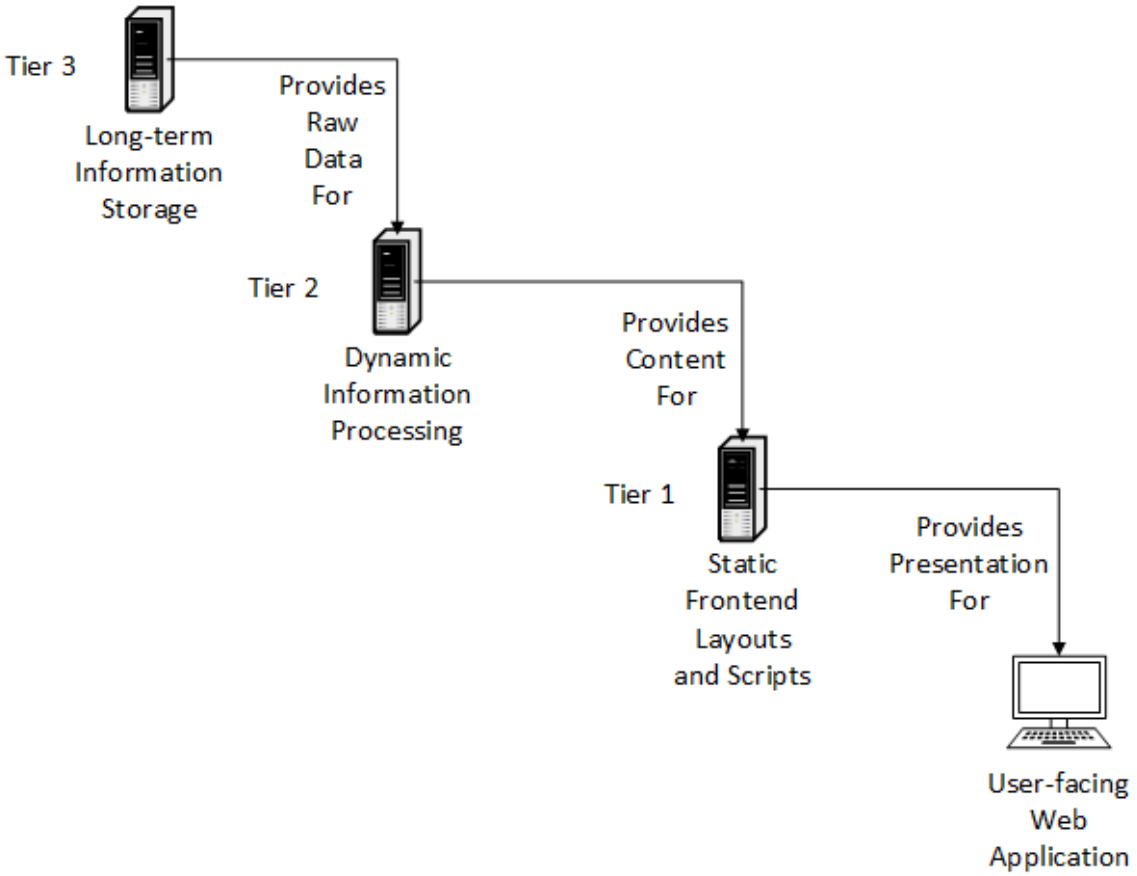


Figure 25: Structure of a Three-tier Web Application

## Front-End Programming Languages

At one time, a web application front-end, by definition, ran in a user's web browser. With the rise of smartphone apps, however, many alternative frontends are also developed to run as native applications on the Apple iOS and Google Android, providing improved experience speeds for applications written in supported languages: Swift or Objective-C for iOS and Java or Go for Android. The widest compatibility, however, is still achieved by targeting web browsers using standard Hypertext Markup Language for content, Cascading Style Sheets (CSS) for presentation, and JavaScript for behavior. These lowest-common denominator languages provide a consistent feature set across devices, from the smartphone to the desktop computer, with responsive design providing adaptation of the presentation layer to any device screen or window size so long as the device includes a web browser conforming to standards used.

## Ajax

A go-between the browser front-end and the web server is a collection of technologies first described by Jesse James Garret under the name Ajax (for the original implementation's use of Asynchronous JavaScript and XML [42]. These technologies allow for rich JavaScript application development by allowing web page content to be updated by the server without reloading the entire web page, as was previously required. In Garret's formulation, Ajax depends on "standards-based presentation using XHTML and CSS" rather than browser or plug-in specific presentation and "asynchronous data retrieval using XMLHttpRequest", allowing for new data formatted according to "XML and XSLT" to be retrieved from the back-end by the interpreted JavaScript in the front-end. The new data is rendered in the browser through dynamic updates of content in the Document Object Model, as implemented in all modern standards-compliant browsers.

The original use of XML for client/server communications is not mandated, and AJAX implementations often use a lower-overhead alternative, such as JavaScript Object Notation (JSON). A comparison of XML and JSON, summarized below, is provided by Simec and Maglicic [43]

| **XML** | **JSON** |
|---|---|
| Requires strict formatting of data according to W3C standards, providing data validation | Formats data directly as JavaScript object, providing no data validation |
| Text-based representation must be parsed and converted to a tree structure for manipulation in object-oriented languages | Parsing is linear conversion of JSON string to JavaScript object; found to execute four times faster in testing |
| Expanding XML attributes allow any data type to be stored | Reduces overhead by limiting to common data types |
| Recommended for use in transmission of documents | Recommended for use in simple client/server data interchange |

Table 8: XML and JSON Comparison

## Relational Databases

In three-tier environments, a relational database management system (RDBMS) is usually most appropriate. Simple data storage as flat files would suggest a two-tier redesign because the back-end DBMS would add overhead with no benefit, while the sacrifice of consistency of NoSQL systems should only be tolerated in the largest datasets where the time cost of an RDBMS query is outweighed by the need for "fast but good enough" insights. A relational database is so named for the relationship between each column of a single row of a table and not, as is often assumed, the ability to define relationships between rows of separate tables using foreign keys. [48] The relational model provides powerful querying capabilities in single-table, multiple-table, single-user, and multiple-user databases. By using a primary key, all known information about, for example, an employee in a database can be retrieved very quickly, and through indexing an unknown employee ID can be found from other information in the relation, such as name or office number.

As an example of the power of the relational database, content management system (CMS) web applications usually store everything about the web site except for presentation, including user preferences and information, hashed logon credentials, configuration settings, and especially the site content itself. The home page is generated by the middle-tier based on a predefined layout and a scripted query to the database for the latest content to show on that page. A ready may click on the name of the content author, a metadata tag, or a date in an archive calendar, which the middle tier translates into a query for the latest content by that author, the latest content with similar tags, or all content from the archive date, and then populates the display with the new query results. All three hypothetical queries will return quickly through using the indexed author key, tag key, and sorted posting date fields. An Entity-Relationship diagram for this scenario is shown in the figure below.

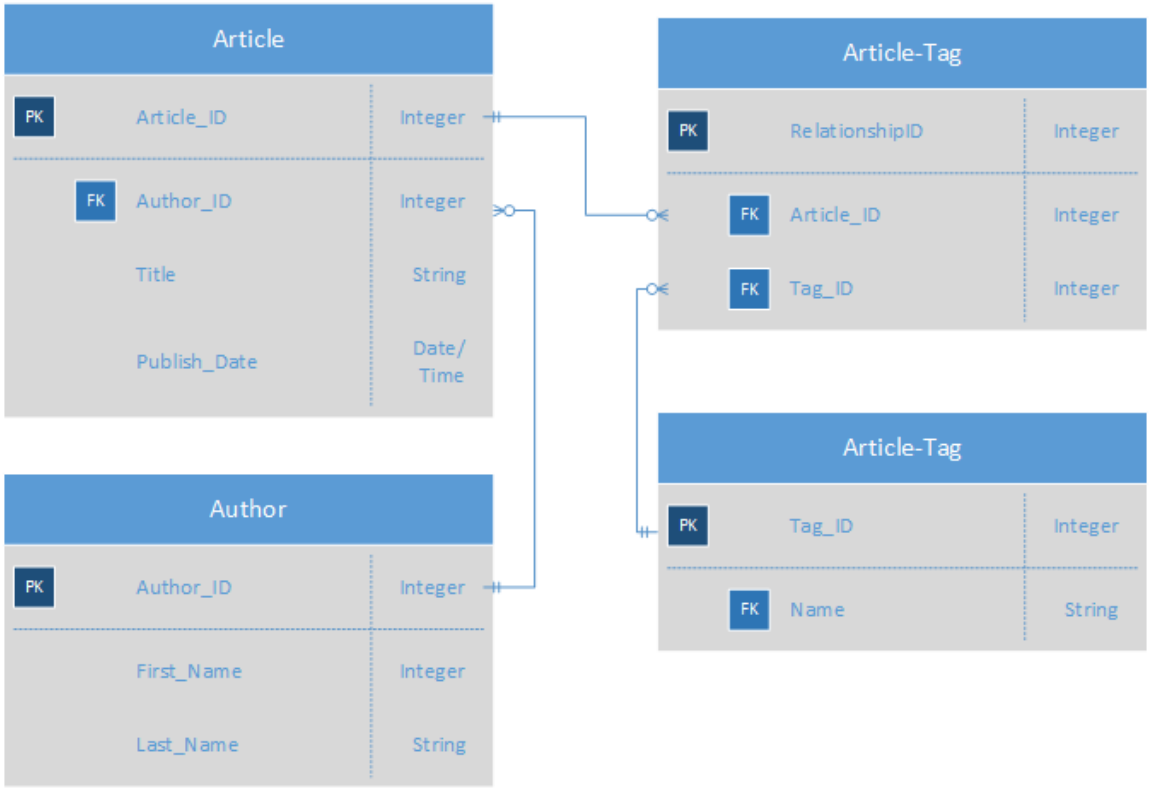


Figure 26: CMS Example Entity-Relationship Diagram

## Web Application Frameworks

Free of the need to run on the many and varied environments of a web front-end, server applications can be developed using a large variety of frameworks, with options for any programming languages in which a developer is likely to have experience. According to Builtwith.com, the most popular web application technologies among the top million internet sites as of November 2016 are those built using the PHP server-side scripting language and those using the Microsoft ASP.NET framework, which supports Common Language Infrastructure (CLI) languages such as C#. PHP is often run as part of the fully open-source LAMP stack, referring to the common deployment scenario where the PHP hypertext processor works with an Apache web server running on top of a GNU/Linux operating system with a MySQL database, whereas ASP.NET may run on the Internet Information Services role of a Windows Server operating system using Microsoft SQL Server. A combination of components from the LAMP stack and the Microsoft solution may also be used, but the use of closed-source software in this scenario incurs significant licensing costs. Each option is detailed in the tables below.

| Operating System | GNU/Linux | Windows Server 2016 Essentials |
|---|---|---|
| **Vendor** | Various distributions | Microsoft Corporation |
| **Cost** | Usually licensed free of charge according to the GNU Public License | $501 [44] |
| **Support** | Free support provided by the open-source community, paid priority support available by some vendors | Provided by Microsoft until end of mainstream support in 2022 and extended support in 2027 [45] |

Table 9:Comparison of Operating Systems

| Web Server | Apache HTTP Server | Internet Information Services (IIS) |
|---|---|---|
| **Vendor** | Apache Software Foundation | Microsoft Corporation |
| **Cost** | Free according to the terms of the Apache License | included in most versions of Windows as a "Windows Feature" |
| **Operating Systems Supported** | Cross-platform source code; binaries usually provided by Linux distributions, Windows binaries are also available [46] | Windows only |
| **Server-side Scripting Languages Support** | Extensible through modules; includes Perl, Python and PHP | Requires Component Object Model (COM) Engine; for VBScript, JScript, REXX, PERL, and Python [47] |

Table 10:Comparison of Web Servers

| Database Management System | MySQL Community Server | SQL Server 2016 Express |
|---|---|---|
| **Vendor** | Oracle Corporation | Microsoft Corporation |
| **Cost** | Free under the terms of the GNU Public License | Free with 10 GB limit |
| **Operating Systems Supported** | Cross-platform; officially distributed both as source code and as binaries for Windows and several Linux distributions | Windows, with Linux version available as Pubic Preview |

Table 11:Comparisons of DBM

## Voice over IP (VoIP)

Well into the mainstream adoption of the global Internet, the Public Switched Telephone Network (PSTN) remained the ideal medium for voice communications. The circuit-switched nature of PSTN, in theory, guaranteed an acceptable baseline quality of service if sufficient network capacity remained to complete an end-to-end circuit. Voice communications over the Internet, now known by the acronym VoIP, had to contend with the Internet's use of packet-switching. Voice data, therefore, can only traverse the Internet after being decomposed into consecutive packets of data. However, no single circuit exists between endpoint hosts, a design which improved reliability by allowing communications to automatically re-route around failing intermediate nodes, but which also posed the practical problem that each packet may arrive by any number of possible routes, often to balance network load over multiple available links. Packets may then arrive out of order, or occasionally even be dropped by the network, and with different delay times between transmission and reception. The differences in active links between two identical networks, one circuit switched and one packet switched are shown in the figures below. In the circuit switched network, the signal follows the same path through the network for the full duration of the call. In the packet switched network, all possible paths may be taken, even some paths that contain loops.

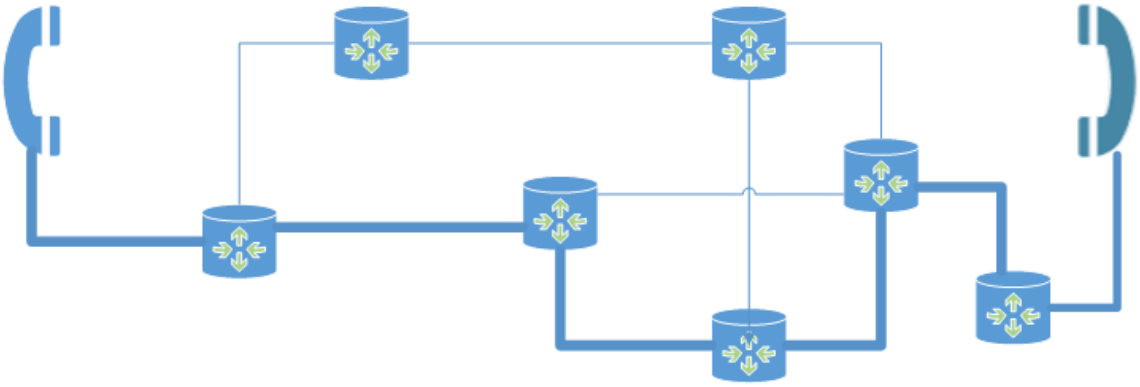

Figure 27: Active Links in a Circuit-Switched Network

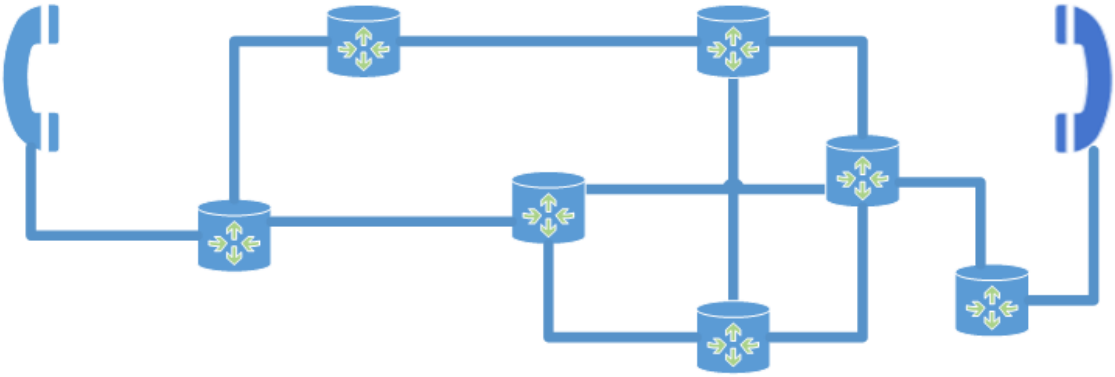

Figure 28: Active Links in an Identical Packet-Switched Network

Communications based on file transfers are largely unaffected by packet switching issues; transport layer protocols number packets for correct reassembly and contain mechanisms for retransmission of lost packets, and it is the timing of any arbitrary packet is irrelevant as once all the file's packets are eventually received. Voice communication, however, requires real-time service in two directions. A packet containing voice data from before the current playback position is no longer useful, and interactive conversations limit the possible buffer sizes, which, per the ITU-T recommendations, cannot introduce more than 400 ms of one-way delay for tolerable quality. [49]

Despite the difficulties of packet-switching voice data, several protocols have arisen to make VoIP a reality. The Real-time Transport Protocol (RTP), developed by the IETF in 1996, provides packet sequence numbering and timestamps for use with transport protocols such as the User Datagram Protocol (UDP), which previously required the Transmission Control Protocol (TCP). TCP requires acknowledgement of every transmitted packet, and mandates retransmissions of lost packets, which is an inappropriate waste for VoIP. The IETF also defined the Session Initiation Protocol (SIP) in 1999, and is now an open signaling standard. In establishing connections, SIP participants negotiate for the best media codec

they have in common, allowing for an evolving range in multimedia capabilities. While some VoIP implementations require proprietary codecs, The Xiph.Org Foundation developed the open Speex codec in 2003 and its successor, the Opus codec, in 2012. Both codecs provide highly efficient encoding of human speech, allowing for discernable communications in low bandwidth conditions and in the face of occasional packet loss, and were also released as IETF standards.

## 3.3 Basic Architecture

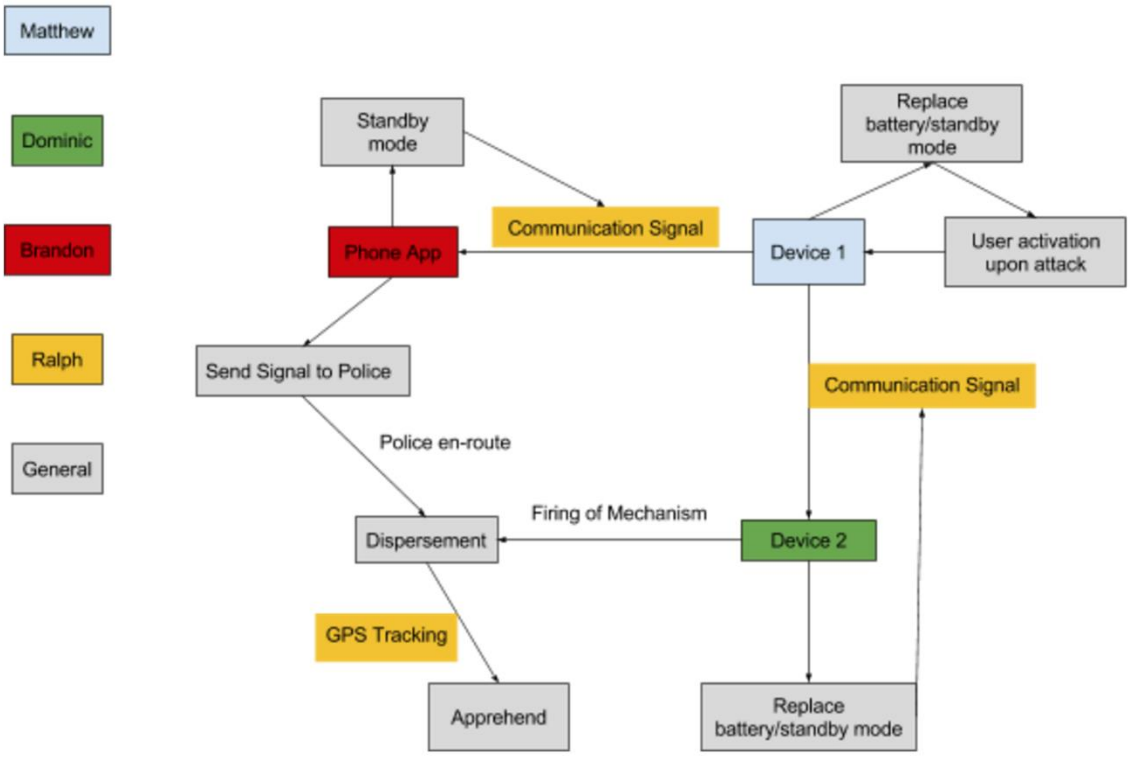


Figure 29: Project Outline Flowchart

## 3.4 Summary of Components

After full research and consideration, the following components were selected for use in the project.

### Power Systems:

Two power systems had to be considered as there would be two different devices that were being created. For the first device, the activator, the coin cell CR1025 was chosen due to its size, as all coin cells in the same family had the same

voltage and continuous current output, with a larger pulsed output. The second device, the LiPo battery with a capacity of one-hundred and ten milliamp hours was selected. The selection was based in the ability to charge by using a simple, freeware charging circuit that can be easily built onto the PCB that will be designed. The LiPo will be able to generate enough current to keep the communication and microcontroller chip turned on as it waits to receive the signal from the other device to activate the mechanisms.


Figure 30:Button Cell Battery

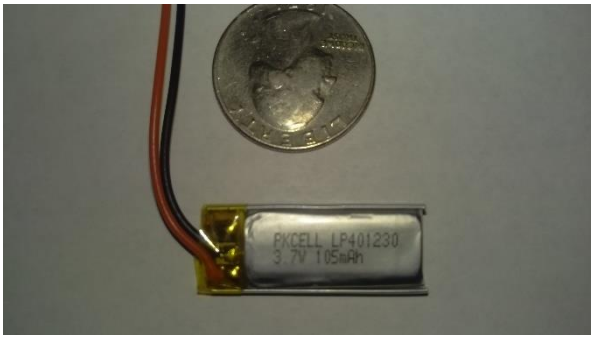


Figure 31:LiPo Battery

## Buzzer System:

For the buzzer system, the magnetic buzzer that was manufactured by Mallory Sonalert Products Incorporated was selected for use as the buzzer to the final device. While on the larger side, pushing the size constraints of the defensive device, the incorporated driving circuit which allowed for a DC input without the use of additional hardware in the design, and uses a lower current reducing the power consumption while on.

Figure 32: Magnetic Buzzer

## Chip:

The microcontroller chip selected for the design was the nRF51822. It is used in both devices as it will be able to provide wireless connectivity between them without the need of another chip, keeping the size low. This chip uses a 32-bit ARM cortex and contains 128kB flash memory. Embedded in the chips is a 2.4GHz Bluetooth transceiver. the chip is seven by seven millimeters in size so it will not have a great effect on the size of the final product aside from the PCB laid out antenna. Both devices will use this chip to communicate and send signals between the devices and the phone application.

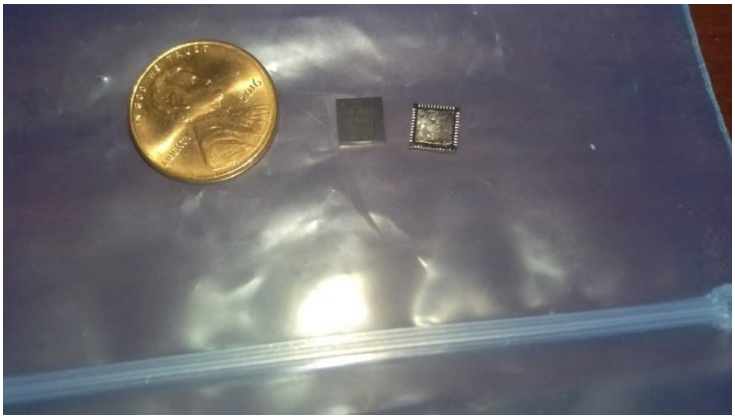

Figure 33: NRF51822 Chip size comparison to a penny

## Switch:

The ideal switch that device 1 will be using will be the mini tactile switch as it allows the group to have the smallest switch that still operates at the ideal specifications for the project. The switch will be housed in a way that minimizes the space needed for the 3D printed design of device 1 as well as to be able to house multiple switches so that the communication device can be activated when a single switch is pressed. The switch is rated at 12VDC and 50mA which is the ideal rating for

the operation of the communication chip and is within range of the coin cell battery that the group will be using. The switches will be connected to the battery and the communication chip using flat wires as it is the best possible option.

Figure 34: Mini tactile switch

## 3D-Printing material:

The 3D printing material this group chose was ABS plastic as it is one of the most widely available plastic on the market. Due to its properties as a thermoplastic, it has the ability to be molded into any shape that the customer wants and it can be heated and cooled a repeated number of times before the chemical properties start to degrade. At $25/kg, ABS plastic is one of the cheapest plastics a person can buy for household use and it is the ideal plastic for this group. Also, due to ABS plastic's properties of being able to resist physical damage, it will be ideal to use this plastic for this group's project as it will be subjected to natural wear and tear.

## Other Components

For passive components and for the LEDs the components will with SMD size 0805/2012 which are 2.00 mm x 1.20 mm in size. This size was choses primarily so that it could be small enough for the limited space on the PCB but be large enough to view the light being admitted from the main device. For testing purposes, these components were simulated with through hole components as they can be used with the prototyping board.

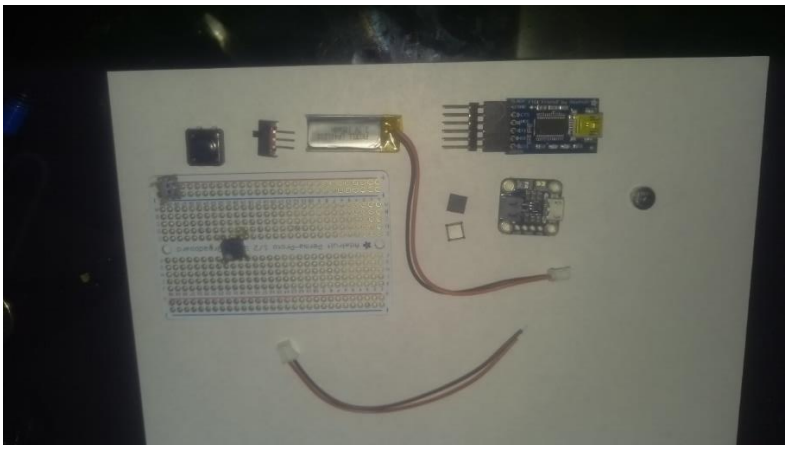

Figure 35: All Components including testing items

The above picture shows all the selected hardware components including the testing circuits. The large board in the lower right, the FTDI Friend, will be used in testing and in the final designs to program the chips as it will be more secure than the other option of over air programming using the Bluetooth protocols. The board to the left of it is the open source designed charging circuit, that the final chip will derive its charging circuit leaving the battery fully embedded in the design of the device.

## Software Components

After reviewing the available software components and technologies available to the group, the team selected free and open standards and software where feasible. The three-tier web application backend will run on a Linux-Apache-MySQL-PHP(LAMP) stack, while the frontend will target the standard-embracing Google Chrome browser running on the nearly ubiquitous Microsoft Windows operating system. Communications between the backend and the frontend will use HTTPS for security and Ajax for interactivity. The Device 1 firmware will communicate with the mobile application using Bluetooth LE, and the mobile application will run on the Android operating system. Communications between the mobile application and the web server will be encoded using JSON and secured using TLS, while emergency communication between the frontend workstation and the mobile application will use SIP and the Opus codec. These decisions are shown in the overview below.

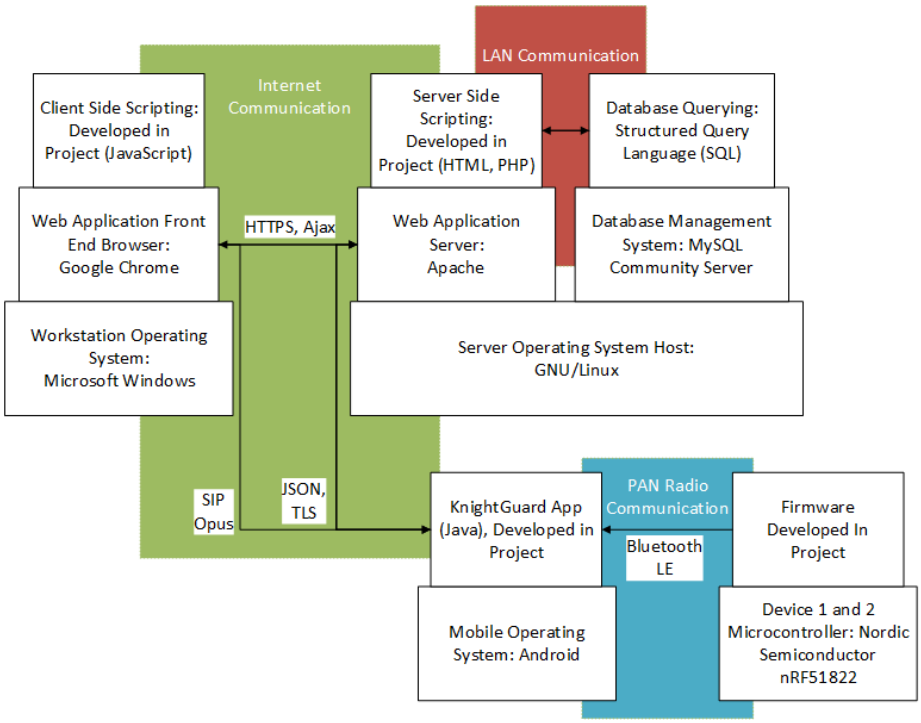


Figure 36: Overview of selected Software Components

# IV. Related Standards & Design Constraints

## 4.1 Design Impact of Relevant Standards

### Personal Area Networking: Bluetooth Protocol (Bluetooth SIG)

Bluetooth is a widely-adopted industry specification for short-range radio frequency (RF)-based connectivity for portable personal devices. Originally developed by the Bluetooth Special Interest Group (SIG), versions 1.1 and 1.2 were ratified as IEEE Standard 802.15.1-2002 and 802.15.1-2005 [7] [38] respectively, with all subsequent versions maintained by the Bluetooth SIG alone. Mostly designed for small, low cost and low power devices, such as headphones and keyboards, the standard as defined by IEEE operates at 3 different classes: class 3 ranging at 1m, class 2 ranging at 10m, and class 1 ranging at 100m. Bluetooth operates at the same frequency band of 2.4GHz as Wi-Fi, but use different signaling methods to prevent interference. It runs at a data rate of 3 Mbps and is used in a personal area network(PAN). Figure 14 shows a chart of different modulation techniques used by not only 802.15.1, but other wireless standards used. [1]

| Technique | 802.11a | 802.11b | 802.11g | 802.11n | 802.51.1 | 802.15.4 |
|---|---|---|---|---|---|---|
| PSK | ✓ | ✓ | ✓ | | ✓ | ✓ |
| FSK | | | | | ✓ | |
| ASK | | | | | | ✓ |
| QAM | ✓ | | ✓ | ✓ | | |
| CCK | | ✓ | | | | |
| Alamouti | | | | ✓ | | |
| OFDM | ✓ | | ✓ | ✓ | | |
| SS | | ✓ | | | ✓ | ✓ |

Table 12:Modulation Techniques

Most Bluetooth products on the market implement one or both of two major Bluetooth SIG specifications, the first being the Bluetooth Basic Rate/Enhanced

Data Rate (BR/EDR) adopted as versions 2.0 and 2.1 using continuous connections that are ideal for application such as audio streaming, and the second being Bluetooth with Low Energy (LE), adopted as versions 4.0, 4.1, and 4.2, optimized for short bursts at longer ranges, ideal for embedded use in the rising Internet of Things (IoT). [39]

The BR/EDR standard, with its higher power overhead and streaming data design would increase the necessary battery size of Device 1 and Device 2, likely beyond the physical constraints of both of them defined in our project specification, to provide the specified battery lifetime. Device 1 and Device 2 should therefore use communication chips or chipsets implementing the LE standard. This has the added benefit of decreasing activation latency by reducing connection establishment time. [37] However, this adds the restriction that the mobile device application may not be deployed to Android devices that only support the older BR/EDR standard. Due to the fact the application is running on devices with an API level of at least 21, the old devices running this older will not be able to have Bluetooth capabilities.

## Secure Internet Communication: Transport Layer Security (IETF)

Communication via the Internet almost always involves the use of connecting infrastructure maintained by third parties, any of whom may attempt to eavesdrop for sensitive information. Furthermore, the remote recipient of any Internet packet may fraudulently identify themselves as a trusted entity, perhaps hiding as a “man-in-the-middle” by forwarding all messages and replies to and from the correct host while monitoring the exchange. Some way of establishing valid trust, message secrecy, and message integrity is therefore advisable for virtually all Internet traffic, which was first developed by Netscape as the Secure Sockets Layer protocol in 1995 and continued as Transport Layer Security by the Internet Engineering Task Force, with the latest version being TLS 1.2, published as RFC 5246 in 2008.

TLS provides private communication through an asymmetric key exchange and the secure negation of a shared secret with which to encrypt all further communications. As weaknesses are found in available negation protocols or encryption methods their use becomes deprecated, and are eventually forbidden by later versions of the standard. The asymmetric key exchange also provides authentication through the public-key infrastructure where trusted Certificate Authorities vouch for each public key that, to the best of their knowledge, the corresponding private key has not been compromised and only the organization

to which the certificate has been issued has it in possession. An eavesdropper may attempt to negotiate the connections for man-in-the-middle attack, but during the shared secret negotiation the eavesdropper must produce their public key, which would not be signed by any trusted Certificate Authority as belonging to the intended recipient, stopping the attack. A flowchart of this process succeeding is given in the figure below. [40]

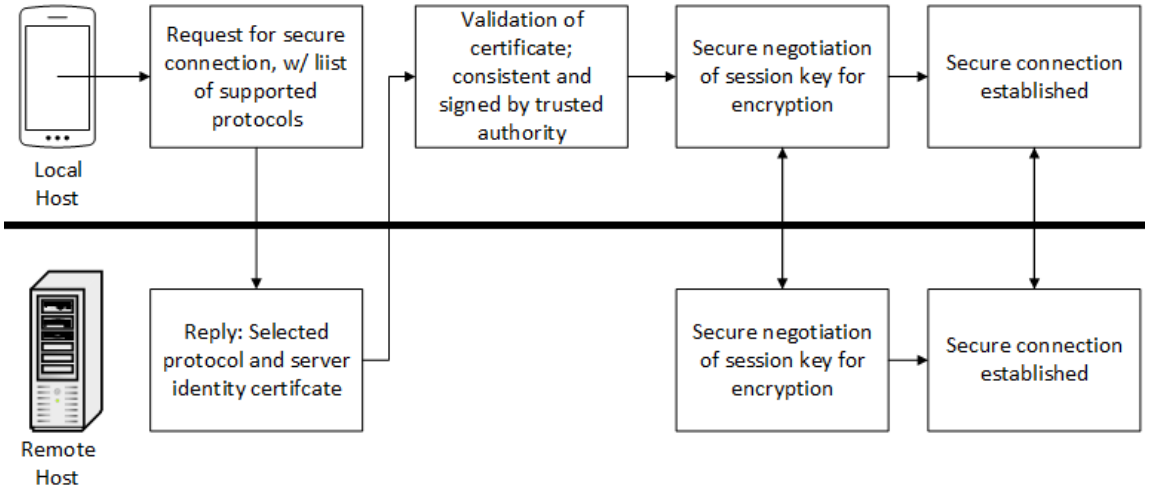


Figure 37: Successful TLS Handshaking

The communications between the mobile device application and the three-tier web application are comprised entirely of personal information transmitted via the Internet, including user email addresses, identifying photographs, and geolocation. It is therefore vital that this communication is secured and authenticated, which shall be done using TLS. For initial development, a self-signed certificate will be used as placeholder, but an HTTPS certificate for the final prototype should be obtained.

# 4.2 Design Constraints

## 4.2.1 Economic and Time Constraints

When dealing with economic and time constraints, one has to look at the possible setbacks on reduce the size of electronic devices. While various electronic devices and parts are getting smaller than ever before, it is hard to judge when a certain product becomes obsolete and as parts get smaller and smaller, typically the cost of the part goes up. The engineering requirements for a chip that contains all the circuitry and components that meets the team's needs and at the same time, be

small enough to be implemented into their project may require more funds than originally calculated. Luckily for electrical engineers, the cost for many of the electronic components are within a reasonable about but for many of them, the man resource is time. For this project, it is necessary for the group to design an electrical circuit that allows the transmission of a wireless communication signal that is then picked up by two different receivers which will lead to the activation of the first device and the app. While some of the economics constraints may be manageable, the time constraints are our biggest problem as the time required to receive a part from the distributor may take several weeks which puts a halt on the project, at least for the testing phase. Along with waiting on a selected part, it is necessary for the team to purchase at least three of each part order as malfunctions, burn outs, and other mishaps might be avoided if this is done.

## Economic:

Dealing the economic constraints for a project of this magnitude would not be as much of an issue compared to time as the various electrical components are all within the economical reach for the group. The price of communication chips, resistors, capacitors and other various parts have all come down. This is due to the various technological leaps that have been taking in the past ten years that allows the small-time engineers be able to work on projects such as this one in a way that does not impact budget at all. The only burden to cost would be the possible rental of a 3-D printing device along with the necessary materials need to print the casing for the PCB. While it would be nice to determine the standards that were set in place for wireless communication, it would not be economically feasible to do so as the price for some standards handbooks would not fit the budget. If the project were to go to market, the final product would be within a reasonable price range for the average consumer. Based on the estimations of the average price for a personal defense device or weapon, the price of the product would be around $100, which is cheaper than a gun or a Taser, but would be more than say pepper spray or some brass knuckles. For the average consumer, it is safer and more reliable than other personally defense products even though using the device may take some getting used too, people would buy a more expensive product if it meant peace of mind.

## Time:

As stated before, the some of the biggest time constraints that the group has is that of actually designing and testing our project design and our finally product along with having to wait on the delivery of parts. Even though the parts are cheap, sometimes it may take a while for the parts to reach us for various unknown reasons. Another possible time constraint that could arise during the project build

is one that has to do deal with coding the communication chip. Coding is a tough task to tackle as one mistake could mess up the entire code and the possibility of starting the code over is a real reality. Also another possible time constraint that could about would be simulating the circuit on a program. The actual simulation part would not take long by designing the circuit and making sure that everything works with one another without having any shorts can be a daunting task. The same goes for testing the project on a breadboard, making sure all of the components work, then testing the project when the final PCB design comes in and more often than not, the original PCB will have faults in it so it is necessary to order another one after more design modifications which would take up more time. In modern day society, time is money and if you can save people time buy giving people the option of spending more money for peace of mind. Another time constraint that might not be so obvious is that when dealing with the timing of the communication chips. With all things in electronics, there is going to be some delay in the actions and we have to account for that. From the pressing of the switch to the activation of the communication chip to the sending of the signal to activate device 2 all has to occur in under 300ms. Any longer than that time a person will notice a delay which may cause the situation that the person is dealing with to escalate. There will also be delay in the activation of device 2 from the reception of the signal to the activation of the defense mechanism to sending a signal to the phone then, there will be delay from when the phone receives the signal to when a signal can be sent out to notify authorities. All of this has to occur under a half a second at least for the product to be effective. Any longer could have catastrophic effects on the victim.

### 4.2.2 Environmental, Social, and Political Constraints

An engineer has to consider the environmental, social, political impact of whatever they design and put on the market. When designing a product, an engineer may consider the impact that the product has on the environment. For example, when dry wall first came out, there was no standards set in place for the materials used in the construction of it and when the discovery came out that one of the materials used causes cancer, the material asbestos, they had to rip all of the drywall out and replace it. Such a product had an immediate effect on the environment and the ramifications of it were severe. A lot of people got cancer from inhaling asbestos. Using the same example, the social impact of when the public found out that asbestos caused cancer was outrageous. People were afraid to even go inside their own homes for fear that they might breath in the harsh material. At the same time, there was quite of few lawsuits that happened as a result of the asbestos exposure. Many companies had to pay out subnational sums to these people affected by it which caused the situation to be political as well with all of the lawsuits

happening. None of the engineers designing the product knew that asbestos would be so deadly so in hindsight if they had known or had a standard to go by, they probably would not have used it in the first place.

## Environmental:

The group wants to make this project as environmentally friendly as possible do to the increasing concerns on how the planet is progressing. That being said, it is important to realize that even though saving the environment, the parts that the group needs are not exactly environmentally friendly. Batteries, for example, are highly toxic for the environment and they need to be disposed of in a proper manner as well as dealing with all of the plastics that this project requires. With all self-defense weapons/ products, it is possible to affect the environment around where that particular goes off. For example, if a person were to be attacked by somebody and the victim used pepper spray, the spray could get on the ground or in any of the surrounding area. Another instance would be if a person had a gun for self-defense and the victim discharges the gun but misses the intended target. There is a possibility of collateral damage to worry about as the bullet simply will not stop unless it hit something hard enough. For this project, however, none of this of concern as the device, when the product goes public and is triggered, the mechanism would be contained in a small area around the victim and hopefully only affect the attacker. Another possible instance is dealing with all the cell phones and other electronic devices that also operate using wireless communication. Much of the technology that operates using wireless communication uses the 2.4GHz spectrum which if there are multiple devices in the area, it could affect the strength of any one particular signal and affect the signal strength of the wireless network. So if there is a large crowd of people all operating on the same wireless network say at a school, then the collective interference from all of the cell phones in the area can greatly affect the effectiveness of the wireless signal. Also another problem that is possible is that water absorbs electromagnetic waves well and since the human body is made up of 75% water, depending on the person, it is possible that the very presence of a human can affect the quality of the signal. It is more often than not that it is not the primary concern of engineers because in order to really affect the signal strength, the person would have to be right next to the antenna. The same principle applies for when a person touches the antenna of a TV or radio and the quality gets better. This is a main concern with our project because it deals with direct skin contact from device 1 which could affect the strength of the signal.

## Social:

Many of the social constraints dealing with any type of device that is supposed to harm or disable a person can be threatening to other people. The average person would rather not know if a person is carrying a concealed weapon as it can put people on edge about their next move. For example, with the recent backlash on the ownership of firearms, the social stigma is that they are dangerous and anyone with one is a dangerous person. There are even studies that back up these claims and one such study found that a person who owns a firearm is more likely to be killed via homicide than anything else. That is not due in part that the person is dangerous but rather that is the nature of how deadly guns are. Most of the deaths that occur do to firearms are not due to self-defense but rather do to dangerous people using it to rob, kill, or other illegal activities. That is not saying everyone should not own one but rather people need to understand that it is not a toy and needs to be treated with respect. In the same instance, this also goes for any device that is meant to incapacitate a human. The final product of what this group is trying to do is it is supposed to knock down a possible attacker in a non-lethal kind of way, but there is a downside to this if the product does get in the wrong hands. It can be used as a weapon to prevent people from doing normal tasks and it can have used as a scare tactic in a crowded area. To prevent this in the future, the future product should have biometric switches to prevent activation by someone other than the person who originally bought it.

## Political:

Many of the political constraints dealing with any type of product is the threat of congressmen passing laws that prevent certain products being made into fruition. Some other constraints may include the use of patients in products as well as the threat that somebody is going to sue for the miss use of the product and or using somebody else’s design. There are constantly new patients being submitted and our group as to be careful about using many of the components that are on the market because there is a risk of using a product and/ or a design without somebody's permission or creating a design that is similar to one already made. Another worry is dealing the lawsuits in a sense that if the product were to go to market and not function the way it was supposed to or fail in a catastrophic way, then there is the possible threat of the person who was affected suing the company because it failed when it was not supposed to. For example, there was the past case of cell phones catching fire due to bad battery installment by the manufacturer and people were getting hurt because of it which resulted in suing the company. Even though the installment was not their fault, they still had to pay for it and because of the social scare that the phones would catch fire at any time, people

stopped by their product out of fear. Our group hopes that is not the case when the product is tested but there is always that worry.

### 4.2.3 Ethical, Health, and Safety Constraints

When dealing with the ethical, health, and safety constraints of any product being designed, one must consider any and all possibilities that something bad can happen at any moment during product testing, development, and/or commercial phase of production. Safety is of the utmost importance for this group and we want to be able to design this product in a way that it will not harm the user in any way. The ideal goals for this project is to have the collection of devices be smaller and more secure than any gun on the market, be safer to use than any handheld personal defense product on the market, and be as easy as possible to use for the average consumer. Should this product go to market, the consumer would have to purchase a dummy kit which would allow them to get used to the device and how they all work together to prevent any accidental triggers. Once the person feels that they are comfortable with their new product, they can trade it in for the real device. This is all for the safety of the consumer as an accidental trigger could have the potential to harm the user and the company would want to prevent that at all cost.

#### Ethical:

Some of the ethical constraints would be concern over the way the defensive mechanism operates. The device would be similar to that of pepper spray in the way it incapacitates the attacker in a way that does not do any permanent damage to the attacker. Also some of the concerns would be using the device to harm for bad rather than to use it the appropriate way. A way that it could possibly harm other innocent people would be activation in a crowded area as multiple people would be affected by the way the device is operated. One of the work arounds for this problem is that when the device is activated the police are notified which will prevent any further harm but it still would take some time before the police arrive so some damage can be done in the meantime. Another possible constraint is the possibility of getting into trouble when using communication chips not rated to any standard that has been already established. A possible workaround for this would be to limit the range on the devices and limit the pairing so that only the three devices only work with each other along with having some dampeners limit the range.

#### Health:

There can be many health constraints when working with electricity as well as dealing with something that is used to incapacitated a perpetrator. When working

with electronic parts on a breadboard, people have to be care when dealing with voltage and current. It is possible for someone to shock themselves on an open circuit or they can possibly kill themselves if the current is high enough. Apart from the risks in building the project on a breadboard, there is a risk when the device is activated and the defense device gets into the mouth, nose, and eyes area, possible causing harm to the attacker in a way that may cause irritation is the areas listed before. Even if the attacker is effected, if there are bystanders nearby when the mechanism goes off, they could be effected accidently which could cause possible legal problems for harming somebody when they did not do anything.

### Safety:

Along with the possible health concerns with building this project, safety is this group's top priority. The main concerns with safety are when building the project on the breadboard, testing the project when it's on the final PCB, and during the final demonstration. There might be the possibility of getting an electric shock when building the project on the board as there is always the risk when dealing with electricity. Also, when the product finally goes to market, it will have the final dispersal method is release. When the device does off, people will be affected by it if they are within range of the dispersal. Protecting the customer is the main priority for engineers but it must be taken into consideration that if the product is not safe itself then how will it be able to protect the customer? For instance, in order to combat possible water damage to device 1, it would be wise for the internal components to be waterproofed in a way so that even when it submerged, it will not be affected. The signal from the communication chip will be greatly affected by the presence of water but the device should still function when it is raining.

## 4.2.4 Manufacturability & Sustainability Constraints

Humans have always strived for the best in themselves and the products they produce. They always look at the things they do with a sense of pride in themselves. This can be seen when looking at the Pyramids of Giza or the Roman Coliseum or anything that has survived the test of time. The same principle applies today in the modern world. Engineers want to walk past a regular convenience store and see their product that they designed on the shelf and say "I designed that" or "I built that". It is the sense of accomplishment that gets engineers out of bed in the morning. Fundamentally, however, engineering has changed over the years when it comes to consumer products when talking about the difference between when products were made in the 1970's and today. Products that were designed and built back then had the built to last kind of mentality. The only problem was that people started to get bored; if the products were building lasted forever, then what is the point of making anything new? What's the point in

innovating or being creative? In today's engineering world, products do have to last a certain amount of time but it's just long enough for the next product to come out to market so that the consumer has to buy the next, best and greatest product they can get their hands on. The project for this group is to make a personal defense device that would last for longer than the average electronic device but at the same time, there will always be the next best thing being designed, built, etc.

## Manufacturability:

When dealing with the manufacturability of anything electronic, a problem will arise due to the fact that manufacturing semiconductors is not a perfect system. Even the most widely produced processors on the planet still have some processors that are faulty and cannot be used and this is due to the semiconductor building process. The same goes for when our group needs to order chips from a manufacturer. Some of the chips we will receive may be faulty and we would not know until we test them on a breadboard. If the chips are faulty then we would have to order new ones. If this project were to go to market, it would encounter the same problem regardless except it would be on a larger scale. It would be awful if a customer were in a life or death situation and the product did not function correctly. That is why it would be necessary to test each individual device to make sure it is working before being sent out to the consumer. Ideally, the outermost casing would be made out of a 3D printed material that way the product can be massed produced for a cheap price while still being sturdy enough to survive a fall. The group wants the outer casing to be able to be durable but at the same time be flexible as well as be comfortable to wear for the consumer.

## Sustainability:

As stated earlier, technology is progressing at an astonishing rate due to the fact that engineers are developing products in a way that forces people to upgrade to the next best thing every other year. This causes engineers to be innovative, creative, and daring as they never know which technology is going to be the next break out one. For this project, if it does go to market, it should be able to last around two years for the average consumer. This does not mean the batteries can last two years but rather, the product has to be reliably for the consumer and be able to last long enough for the next upgrade to come out. Should this product go to market, it would have an everlasting effect on a person's wellbeing which will drive consumers to purchase this product. Ideally, this group wants this product to last for a long time commercially, meaning, last a long time through multiple upgrades throughout the years. Maybe the first year will only have the minimum requirements for the product to be effective but future upgrades could have water proofing for device 1, government or military applications, touch sensors on device

1 that allow it to be only activated by a finger print, etc. There is plenty of other technologies that can be used to help this product in the future that is not currently feasible for this project. For added sustainability, the outer casing will be dipped in rubber to add water proofing and to provide added comfort for the consumer. Should the final product go to market, a latch would be added to the devices to allow access to the battery that will allow the battery to be changed out with ease.

### 4.2.5 Customer Related Constraints:

Time: Not everyone will be available at certain times during the time this project is being developed. We will need to work out a schedule that best fits each of us so that way we will be able to produce a working product. It also has to be taken into consideration the time it takes to build the different circuits on the PCBs as well as dealing with the time it takes for shipping said products to be available to the customer.

Signal: The signal between devices would need a max range of five feet so that they will only work together, but another signal would have to have a range of several miles, as to reach a police station. This is so that should any one device falls into the wrong hands, one device cannot be used without the other along with not being able to use for mischievous purposes.

Lifespan: We need to figure out how to keep the amount of power used on the devices low enough so they can meet the design specifications before it runs out. We also need to figure out if wireless charging can be implemented within the allotted time or whether we have to utilize another type of connector. Device 1 can utilize replaceable batteries.

Communication: We need to figure out which way of communication is best suited for this project. A near field communication device would be the easiest implementation, however there may be an alternate system that can provide a more secure connection between the devices.

Cost: The cost of the components need to be minimal so that the final product will be affordable and accessible to everyone, while also having high quality components that will not fail when the device needs to be used.

# V. Hardware & Software Design Details

## 5.1 Initial Design Architecture

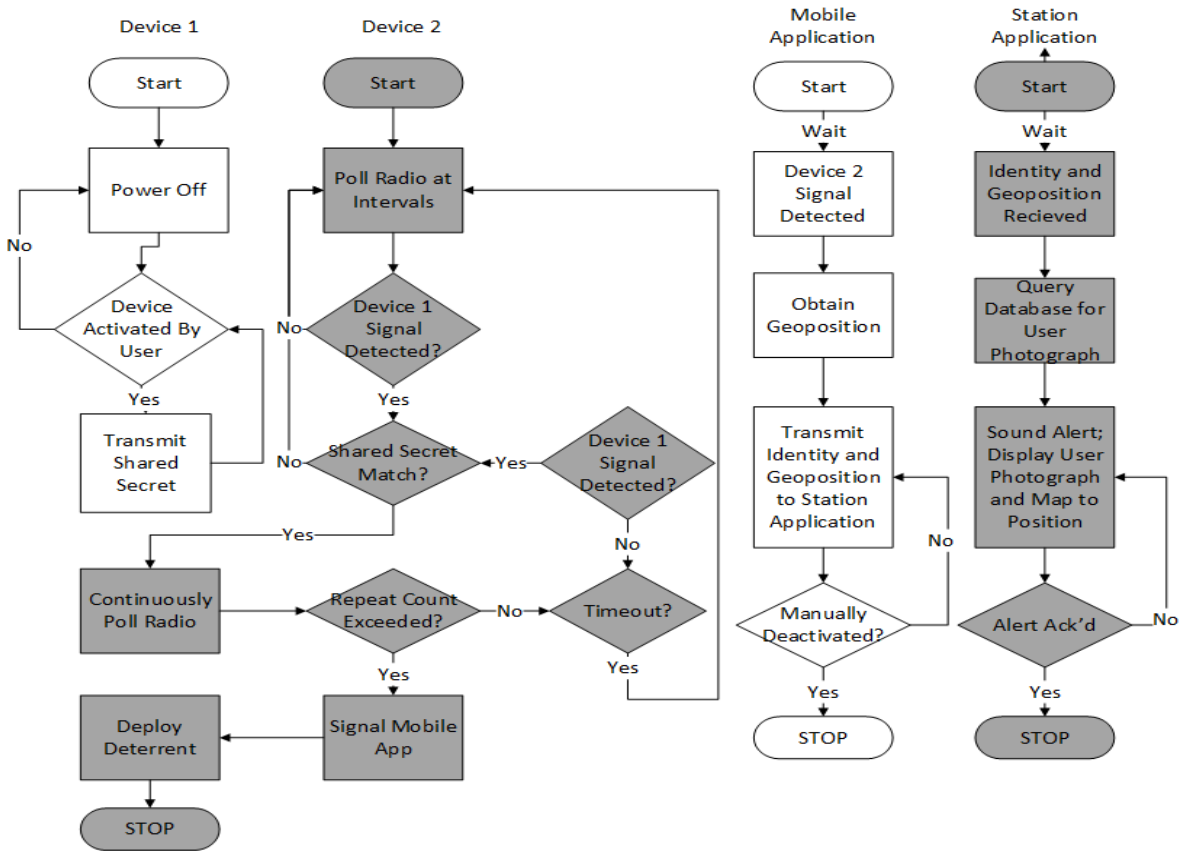


Figure 38: Logic flowchart for the devices

## 5.2 Device 1

For this project, the group wanted to have a system that used a close range wireless signal to activate a second device that would in turn activate the app on the phone and trigger the device mechanism. For demonstration purposes, the project will not include the defensive mechanism but inside will have a light and a buzzer to indicate a successful reception of the signal and activation. Device 1's primary purpose is used a switch that, when activated, would send a signal to Device 2. Device 1 will be small enough so that if a person were attacked by someone from behind or from the front, the attacker would have no idea they have something on them. Ideally, Device 1 would be the size of a key fob. Person would only have to trigger one of the two switches on the activator for it to activate the communication device in Device 1. If a person were in a struggle with somebody

or a life or death situation, all the person would have to do is click the switch with the fingers using one hand. This allows a person to activate the mechanism even though their hands are tied or if they are in a bear hug.

For the sake of simplicity, device 1 and device 2 will have the same communication chip as coding for both of them would be easier compared to if they were different chips. While device 2 is more complicated in terms of circuity, device 1 has complexity in the size of the device. Device 1's size is going to be the main limiting factor for this group as limiting the size of the device also limits the kind of circuitry can be implemented into device 1. Current projected design implementation shows that only two switches, a battery, and the communication chip will only be on the PCB for device 1 in order to reduce size, complexity, and to reduce power consumption. For device 1, the ideal goal is for the battery to be one time use as the battery needs to supply enough current in order to activate the chip just long enough for the chip to turn on and send the signal. By adding complexity to the circuity for device 1, more features can be installed such as filtering out other unwanted signals, making the signal only work in a short range, adding multiple switches, etc. All of these add to the size for device 1 and it will not be beneficial for certain components but for others it would add needed complexity.

The main purpose of device 1 is to act as a key fob like trigger. A key fob, for a car, works by sending a signal to the car based on the user input to the device. When a person presses, for example, the button to lock the doors, the key fob sends a signal based on the button that was pressed which then locks the car doors. The same goes for if the person presses the open trunk button or the unlock door button. Device 1 works the same way, when a person presses the button on device 1, a signal will be sent to device 2 which will trigger the defense mechanism.

## 5.3 Device 2

As previously stated, device two will use the same communication chip as the first device. The chip in this device will be used to receive the signal from the first device, as well at send a signal to a connected phone indicating when the device has been activated. Upon receiving the signal of activation, the microcontroller will send a signal through its output pins to a MOSFET device. Upon receiving this signal, the device will act as a switch and allow for voltage from the battery to pass through to the defensive mechanism. In testing, this will be replaced by a buzzer system as well as an LED.

Device two will also contain its own charging circuit on the PCB. This allows the battery of the device to be fully integrated on the circuit, as the device will need to be on constant standby awaiting the signal from the first device. To save space on the PCB, the charging circuit will be placed on the opposing side of where the

battery is located. As the buzzer and LED systems on the PCB are an allegory to the final self-defense device being developed by the company, a larger portion of the PCB size will be allotted for them, limiting the space for the other components to ensure as small a final design as possible.

The outer casing of the second device will be produced by a 3-D printer using ABS for its sturdiness. The casing will have the port to plug in to charge the internal battery, as well as small vents to allow the sound to propagate outward for testing. The casing will also have small holes to allow the viewing of the LED in the device when activated.

# 5.4 Software Design

Software will consist of three major parts, each of which will be developed as separate sub-projects, with separate personnel having primary responsibility for each. These first sub-project involves the microcontroller firmware on both the user triggering device (elsewhere referred to as Device 1) and the active deterrent module (elsewhere referred to as Device 2). The second sub-project involves the software running on the user's mobile device, with an initial target platform of Android-based cellular telephones. The third sub-project encompasses a full three-tier web application, to store user information such as name, age, and an up-to-date photograph submitted via the mobile application, and to display this stored information on a workstation in response to the activation of Devices 1 and 2, along with the latest geolocation of the user as provided by the mobile application, in order to provide an alert to law enforcement that the user is in danger.

## Software Requirements

The Device 1 and 2 firmware shall

- Establish and maintain Bluetooth pairing and communication security between Device 1, Device 2, and the user's mobile application device
- Activate deterrent and attempt to signal mobile application upon non-accidental activation of triggering mechanism
- Send distress signal to mobile application from Device 1 and Device 2 upon triggering and activation of deterrent respectively
- Establish Bluetooth connectivity between devices within 0.3 seconds from standby

The mobile application shall

- Register and verify new users in conjunction with web application using cryptographically secure protocols and validation codes

- Accept user data to include name, date of birth, email-address, username, password and identifying photograph
- Obtain approximate user position from device location services
- Transmit user identification and position with distress signal to web application and open voice communication upon non-accidental activation of Device 1 triggering mechanism or in-app distress button

The web application shall

- Maintain a database of user information submitted by mobile application
- Generate and send via email validation codes for user registration
- Identify and authenticate distress signals from mobile application
- Display on front-end workstation user information, including name, age, photograph, and location and sound workstation alarm upon receipt of distress signal
- Establish two-way voice communication between front-end workstation and mobile application upon acknowledgement of distress signal

These requirements have been defined as a baseline level of functionality required by the sponsor and faculty advisor, and are subject to revision if additional desired functionality is deemed achievable by the project team and requested by the sponsor, necessitating review of requirements in the first phase of each of multiple development cycles. In particular, the vague term “non-accidental triggering”, will be specified and revised after usability tests of device mockups establish an optimum response time trade-off between confidence in intentional triggering and minimized deterrent activation latency.

## Mobile Application Detailed Design:

Included with both devices, we also have come out with a phone application on the Android OS mainly for the use of keeping all of the users together in a database. When opening up the phone app for the first time, the users must sign up and include the name, age, a unique username and password, as well as a picture of the user of the device to put the information within the database. When the user submits their information, an email will be sent to the one that the user provided in order to verify the transaction through the use of a randomly generated number to act as a code that needs to be input. All of this information is then put into a database made in MySQL in order to store all information for when the alert signal from the device is turned on. When device 1 is acknowledged, a communication signal will be sent to the phone app, which will then send out a signal to a local police station, which will then pull up all the information within the database, as well as the location of the user, which will be tracked with the use of the GPS system within the phone. While the police are en-route, the phone app will then go into a standby mode where the GPS will be in use, the microphone opened so that

audio is transmitted from the user to the police station, and the signal from device 1 will then cut off. When the police arrive at the location, the GPS will shut off and the app will be in its initial state before the signal was first received. Although the phone is generally the first thing that is either taken away or thrown away from the user, we still wish to allow the user to feel some type of comfort and to be able to contact police in a quick and responsive manner.

## Mobile Device Usability and Experience:

Mobile phones have been getting increasingly more technologically advanced ever since they were first globally released in the 1990s. This rapid increase in the technological advancement can be seen easily with Moore's Law, which states that about every 1.5 - 2 years, the number of transistors on integrated circuits double. Doubling the number of transistors exponentially increases the processing power of the computer chips included in phones, and by having these smaller chips with more processing power, phones were able to continually get smaller and smaller. And with the extra space now made from making the chips smaller, more space is opened up to expand upon other features, such as a longer battery life and improved networking speeds. With the culmination of this advancement in mobile development in the iPhone made in 2007, multiple generations of Apple, Android, and other operating systems have been made with thousands of these phones getting shipped each day. Nowadays, newer generations of phones are able to be made every year or 2. As of 2015, about two-thirds of US citizens are now owners of a smartphone. They had become so popular that it was reported that in late 2010, smartphones were able to outperform personal computers in sales. A major boon to the mobile usability is the inclusion of internet access. With the internet now on phones, users were able to bring their computers on the go in their pockets, and could access multiple online services, such as online games, social media, watch videos, and other activities only capable of being online. Add in the unlimited data plans that some phone service providers have and people can now access the internet 24/7 wherever they go, with about 85% of the users belonging to the age group of 18-29. The figure below shows some popular features that smartphone users constantly use [14]. Smartphones also range from the touch phones, such as the iPhone, to non-touch screens, such as the BlackBerry. Along with companies creating their own apps, users can also make their own. Building apps is now on a personal level where anybody can make an app if they want, with the help of IDEs such as Android Studio. The developer of said app can then if they want to publish these apps into a digital distribution or media store, such as the Google Play Store, where others can download or purchase your app. To become a publisher, they would need to pay a one-time fee to have access to a publisher account.

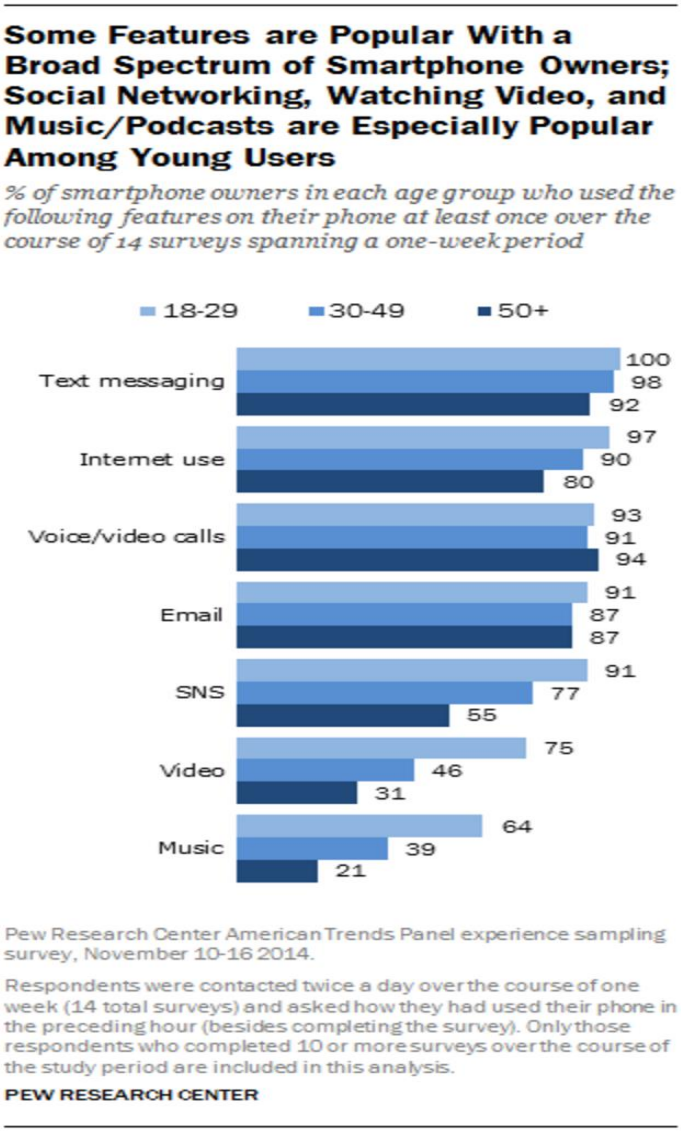


Figure 39: Popular Features of Smart-Phones

## IDE:

The integrated development environment(IDE) is a software suite that brings together all the basic tools developers need to write and test software. An IDE usually consists of a source code editor, a debugger, and sometimes come with either a compiler, a linker, or both, or it can sometimes come with neither. Rather than performing all the steps required to make an executable program as unrelated individual tasks, it brings all the tools needed into one application and workspace. The alternate to using an IDE is a simple text editor, which you can use to edit plain text files. An IDE will sometimes be used over a text editor due to the fact

that since it is integrated, it allows you write your code as well as debug it at the same time, whereas in a text editor, you would have to debug your code in an external debugger. Using a text editor also doesn't give you corrective responses, which is an easier way to fix potential errors your code may possess. Not having corrective responses, auto-indenting, and other features that come with an IDE makes writing on a text editor very hard to use nowadays. Figure 40 shows a basic diagram of the IDE architecture. In this architecture, you are able to see the editor, compiler, linker, and debugger that make up the IDE. Along with this comes a search engine, source browser, and symbols database, all which assist in code navigation and build control to make the IDE an easier place to navigate.

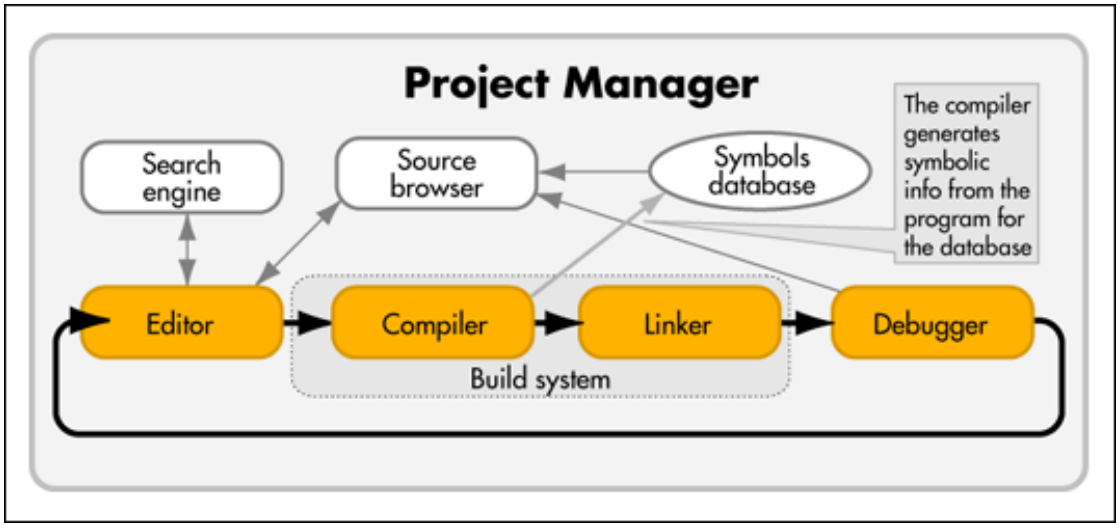


Figure 40: IDE Architecture

## Android Studio:

### General Information

Android Studio is the official IDE that can be downloaded by Windows, Mac OS, and Linux that replaced the Eclipse Android Development Tool(ADT) as Google's primary IDE for android application development. Based on IntelliJ, an open source IDE, Android Studio is built around a flexible build system called Gradle, a Java based automation system that takes away the use of going to the command line in order to build your project. Due to some developers not knowing each of the tools needed in the command line, Eclipse had built their own build system in order to avoid going to it. In a build system, all source files are taken and then, converts them to their appropriate file type, and groups them into a compressed folder, which is the APK. Android Studio differs from Eclipse by not only having this Gradle system, a completely simplified, redesigned user interface design tool, Android Studio also provides you with an emulator built into the system, and the fact that Eclipse needs to integrate the ADT manually, whereas Android Studio

automatically has the ADT integrated. The IDE is broken down into 3 folders, manifests, which contains the androidmanifest.xml file which describes the fundamental characteristics of the app and defines each of the components used [16]. XML is a markup language that was designed to store and transport data that can be human and machine readable. The next folder is the java folder, which contain all of the java source code files. The last folder is the resource folder which contains all non-code resources not directly found on the java classes. Features that are in Android Studio include a layout editor that allows users to drag-and-drop UI components, Android-specific refactoring, and support for building Android Wear apps. [19]

## NetBeans:

Netbeans is the official IDE for Java 8 that is downloadable by Windows, Mac OS, and Linux operating systems made by the Oracle corporation. The Netbeans IDE lets you easily and quickly make Java applications for either the desktop, mobile, or web applications. Netbeans is a free and open source so that everybody will be able to make applications that can potentially benefit anybody. Several programming languages besides Java can develop applications for this IDE, such as PHP, HTML5, and C++. Netbeans is built around many build systems, with the main one being the Apache Maven build system, a software project management and comprehension tool, to help manage project dependencies, reports, and documentations from a central piece of information. The default project system is built directly on top of the Apache Ant build system, a Java library and command-line tool that drives processes as targets and extension points dependent on each other. All project commands call targets in the project's Ant script, allowing you to build and run your project outside the IDE like it is inside the IDE. Netbeans differs from Eclipse in that Netbeans uses a different user interface and workflow then Eclipse, but at the expense of not having features that Eclipse has. Netbeans also differs from Android Studio besides the different build systems due to an easier use of shortcuts and refactoring, which is the process of restructuring an existing body of code, which changes its internal behavior, without changing the external behavior. This IDE is broken down into 4 main folders, the source and test packages, that hold your java pages, and your regular and test libraries.

## Eclipse:

Eclipse is an open source community of tools, projects, and collaborative working groups that can be downloaded by Windows, Mac, and Linux operating systems. Mainly use to develop code in Java, Eclipse provides IDEs for almost every language possible, including famous ones like C/C++, PHP, and JavaScript. Eclipse uses the Eclipse ADT build system. This platform can develop rich client

platforms, integrated development environments, and other tools. Eclipse is broken down into the source file, which hold all your java classes, and your system libraries, which hold all the standard libraries that come with Eclipse.

## Platform Architecture:

Each of the IDEs mentioned above have their own unique architecture that makes them stand out in their own way. We'll be talking about each of these architectures and how they would help in our decision to choose which IDE to use for the mobile application.

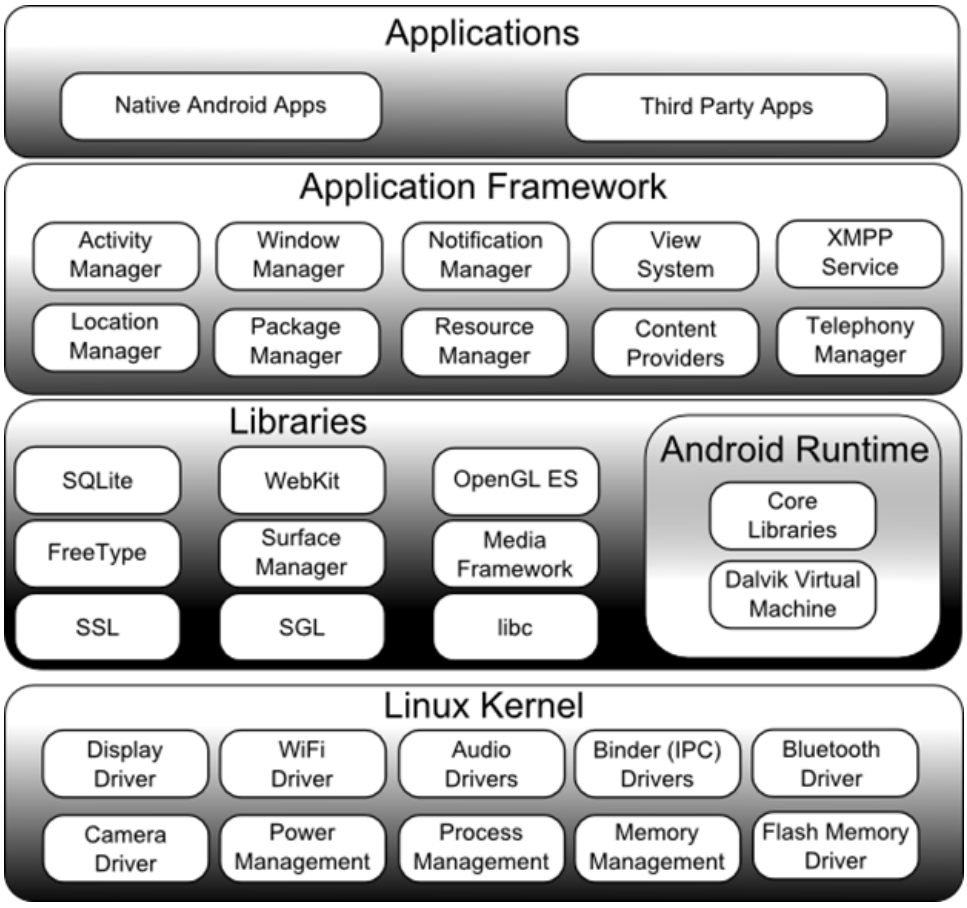


Figure 41: Android Studio Architecture

## Android Studio Architecture:

The Android Studio architecture can be broken into a stack that include applications, runtime environment, libraries, operating system, and services that can be seen better above. Each layer of the stack, and its elements within each layer, are tightly integrated and carefully tuned to provide the optimal application development and execution environment for applications developed on Android. At the bottom is the Linux kernel, which provides a level of abstraction between

the device hardware and the upper layers of the stack. Based on Linux version 2.6, this version provides preemptive multitasking, core system services, device drivers for hardware, and other things. The next layer on the stack is the runtime management, which translates bytecode down to native instructions required by the processor when an application is loaded onto the device. Doing this allows for faster application performance and longer battery life. Along with the standard Java libraries, this architecture comes with its own Android libraries, as well as C/C++ libraries. The next layer is the framework, which is a set of services that collectively form the environment in which Android applications run and are managed. This framework includes services such as activity manager, resource manager, notifications manager, content providers, and other services. The last layer is the application layer, which include both the native applications provided with the particular Android implementation and the third party applications installed by the user after purchasing the device.

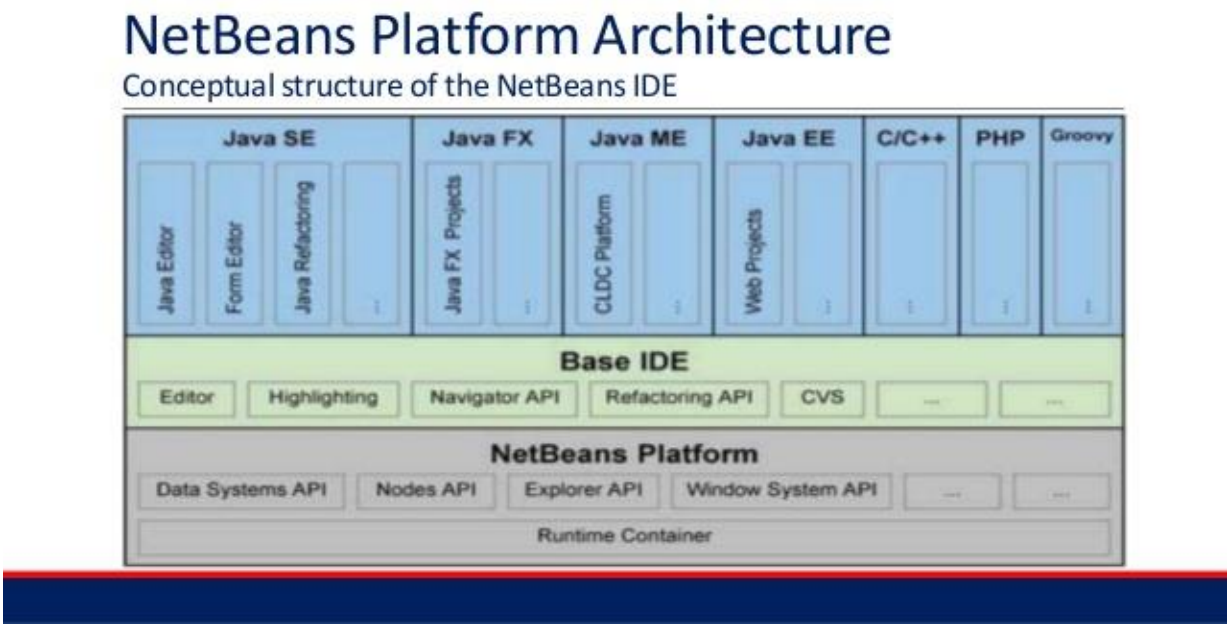


Figure 42: Netbeans Architecture

## Netbeans Architecture:

The Netbeans architecture also takes the form of a stack architecture. Since the platform architecture is modular, it is easy to create applications that are in good shape. The modular nature of the architecture gives the power to meet long and complex requirements by combining many different small, easy modules covering some application features. The base IDE gives you skeleton applications in the form of project templates for all the technologies it supports. It also includes an

advanced multi-language editor, Debugger and Profiler, as well as tools for versioning control and developer collaboration. The top layer contains all the different editions that Java has come up with, as well as C/C++, PHP, and other standard templates in order to create applications.

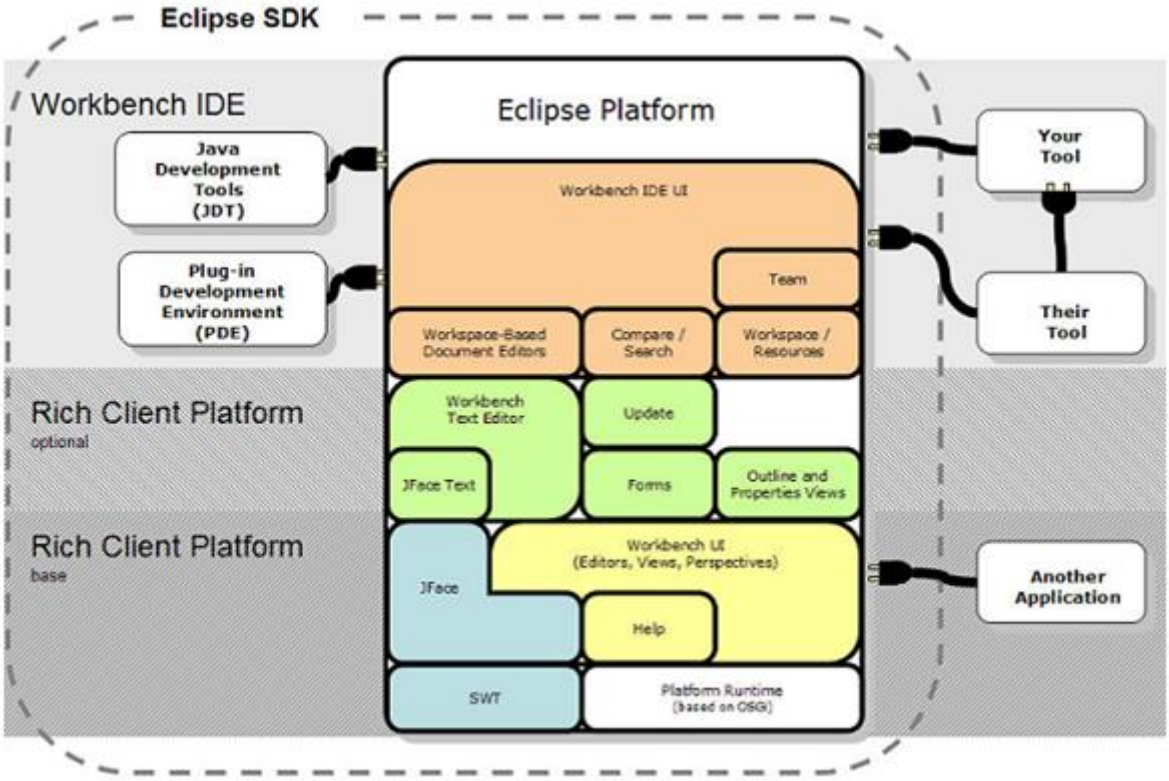


Figure 43: Eclipse Architecture

## Eclipse Architecture:

The Eclipse architecture is structured around the concept of plug-ins, software components that add a specific feature to an existing platform. These features can be in the form of code libraries, platform extensions, or documentation. These plug-ins can define extension points, which are well-defined places where other plug-ins can add functionality. This standard development kit(SDK) besides the main platform includes 2 tools for plug-in development, the Java development tools and the plug-in development environment. The JDT implement a full featured Java development environment, whereas the PDE adds specialized tools that streamline the development of plug-ins and extensions.

## Which IDE to Use:

Based off the information gathered, we figured that the best IDE to use for our mobile application would be to develop it in Android Studio. The reasons behind this was because of the ability to be able to have a side by side view to see how

the code would change the visual aspects of the application. It's easy to use interface along with its own android libraries allow for a better grasp at what we are mainly trying to accomplish, building an android application. Since it has an easy to use interface, it allows us to not be as code heavy dependent like in Netbeans and Eclipse. Also with the ability to keep all the java files in 1 folder, and the xml files in its own folder, this organization of files allow for easy access to the correct file that one is looking for.

## Web Application Detailed Design

The web application will be based on a three-tier architecture, with a co-located web server and database management system serving a client workstation through a web browser. The database design will consist of a single table, with the user's Device 1 serial number as the primary key, facilitating vital information retrieval during a distress call. The web server will generate the frontend display using PHP scripting, with informational updates delivered using Ajax. The frontend display will include an embedded Google Maps display, defaulting to the area surrounding a server-configured location zoomed to the display level of individual streets, such as the vicinity of the frontend workstation. Every five minutes, the layout of the display will cycle, so that no pixel remains static for an extended period of time, reducing the probability of screen burn-in depending on the type of display used.

The web server will also host a minimal HTTPS POST page to receive JSON-encoded information from the mobile application. In normal operation, the mobile application will transmit user registrations and user information updates, which will trigger a database INSERT or UPDATE query as appropriate. New registrations will be denoted by a false BIT-type field indicating that the user e-mail address has not been confirmed. Upon new user registration, a time-expiring confirmation code will be sent to the registered e-mail address. If it is entered into the mobile application within the time limit, the confirmation field will be set to true. Once time expires, the option to retry confirmation or update the e-mail address will be presented.

In emergency operation, the mobile application will transmit a distress signal through the HTTPS POST page containing at minimum the user identity but also if possible the mobile device's current latitude and longitude. A push notification will be sent to the frontend to trigger an alarm tone, and all available information associated with the user identity will be retrieved from the database using a SELECT * query and displayed on the frontend. If the mobile device location is available, The Google Maps display will re-center at the detected location with a highlighted area indicating the current level of precision available to assist in directing rescue personnel. The web server will also provide routing information to

facilitate a VoIP session between the frontend and the mobile device, so that an authoritative voice can further dissuade a determined attacker.

The core elements and data flows of this design are illustrated in the figure below.

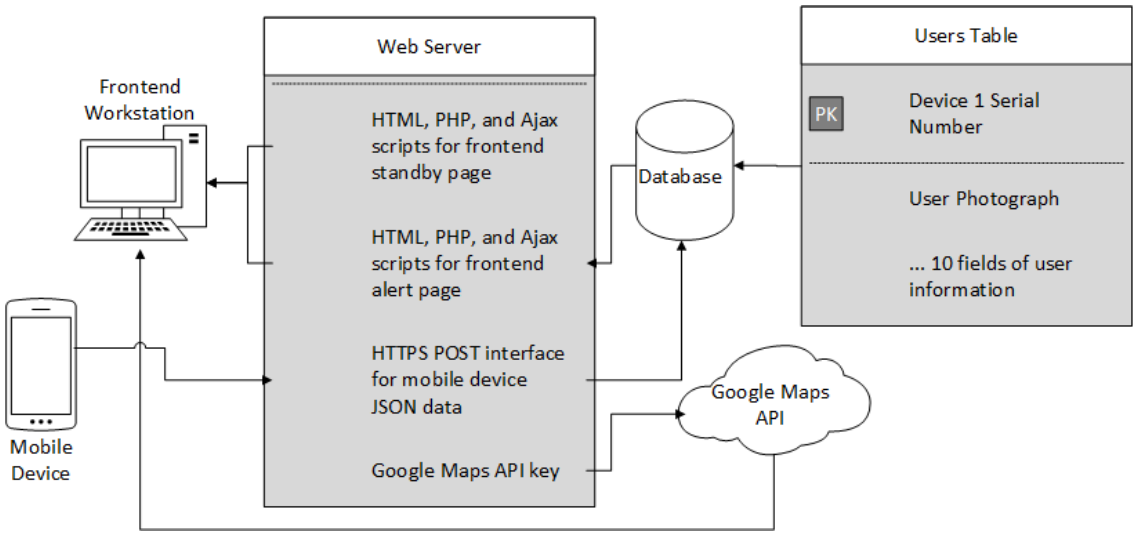


Figure 44: Web Application Detailed Design

# VI. PCB Design & Final Coding Plan

## 6.1 Hardware Diagrams

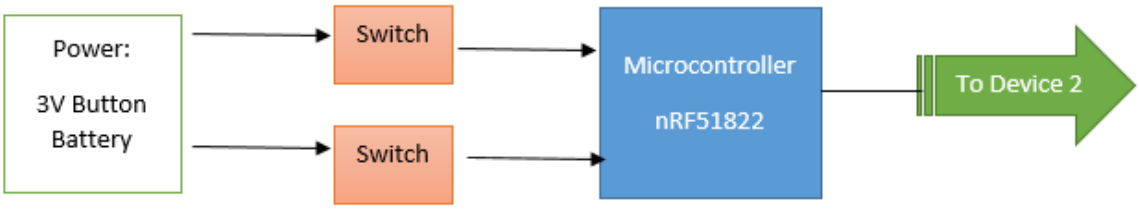


Figure 45: Device one Hardware Block Diagram

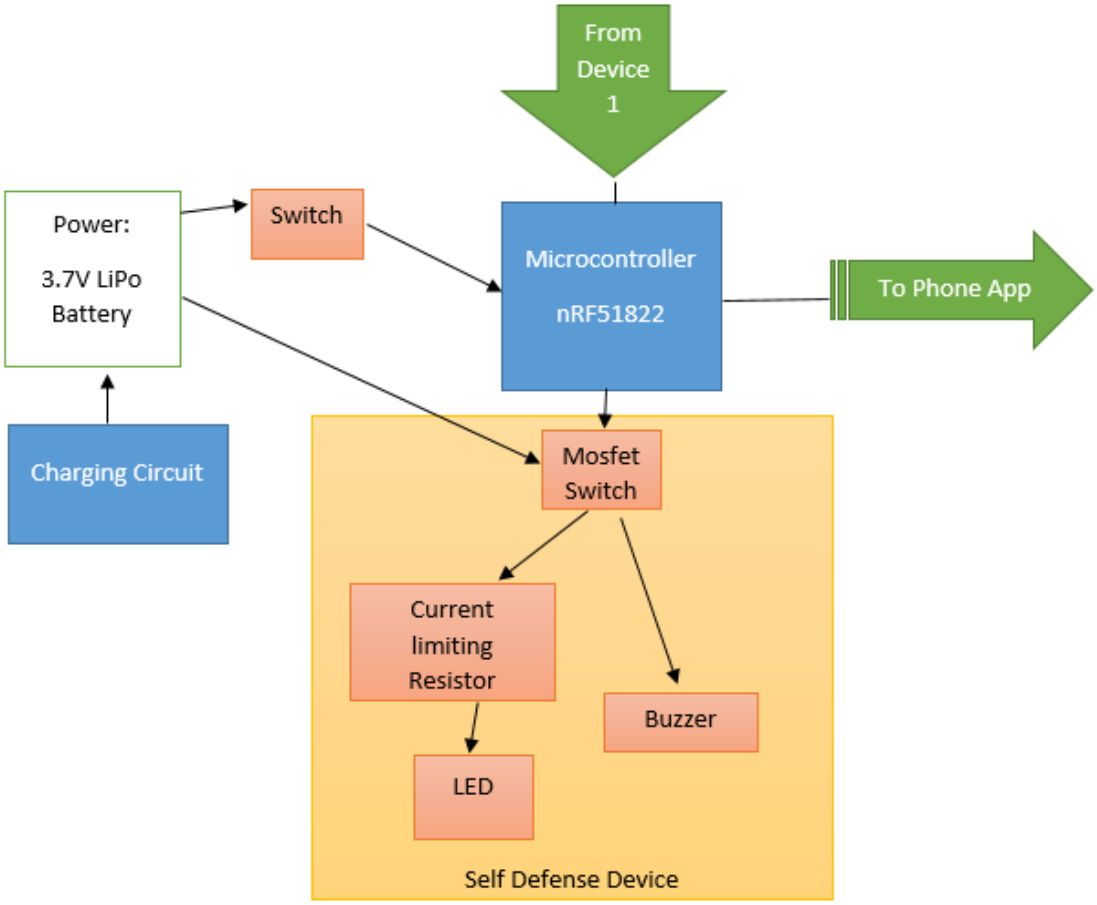


Figure 46: Hardware Block Diagram

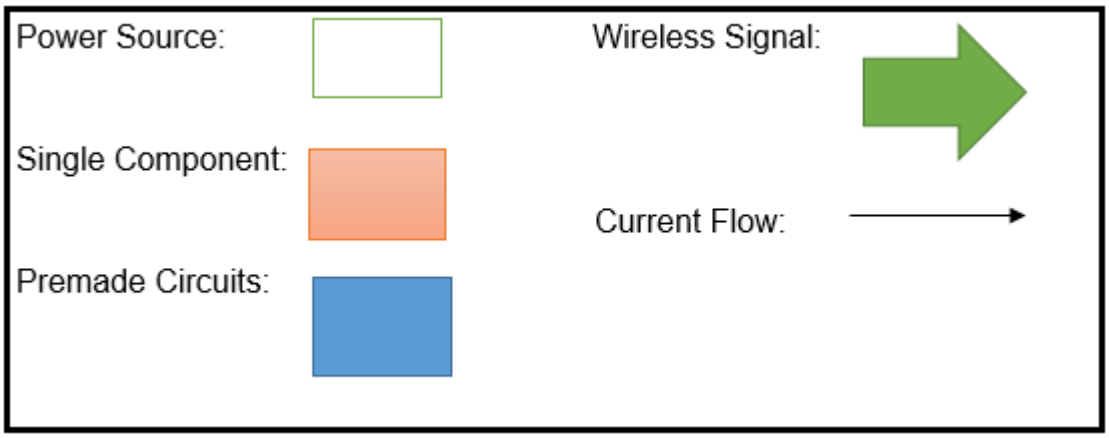


Figure 47: Block Diagram Key

The above figures are the block diagrams for the hardware circuitry. For device one, a replaceable button battery cell powers the microcontroller when a switch is pressed, allowing for a signal to be sent to device two. Device two will be powered by a rechargeable LiPo battery that will be charged with an integrated charging circuit. A switch will be placed between the power source and the microcontroller for off times that the user would like to try to save power, although the device will be designed to allow the microcontroller to be on at all times. When the signal is received from the first device, the device will send a signal to the phone app, as well as sending a signal to the mosfet, which will allow the voltage from the battery to pass though and activate the components in the self defense mechanism or the buzzer and LED. The LED will be accompanied by a current limiting resistor, so not to overload the diode and burn it out upon activation.

## 6.2 PCB Layout Design

For designing the PCB, PCB venders recommend certain practices that will allow for the most efficient designs. While some, such as how to design a high frequency line or to use blind or buried VIAs, are not applicable to the two devices, practices such as rounding trace lines and crossing opposing traces on different planes at an angle. When a trace must be bent on the board, it is always a good practice to curve the lines and not have a strict ninety-degree angle. This is to maintain signal speed because sharp turns slow the flow of the electrons. The PCB layout software that will be used for PCB fabrication, Eagle, recommends using forty-five degree angles because it doesn't affect speed and is not as costly as rounding traces for some venders. Crossing traces on opposing planes should be as close to ninety-degree difference as possible. This will decrease the chance of the signals effecting each other, known as cross talk. If the signals interact, the end signal may not read as supposed to. In our devices, this could be detrimental as the

interference could cause the self defense mechanism to not activate when needed, effectively negating the reasoning for having the device.

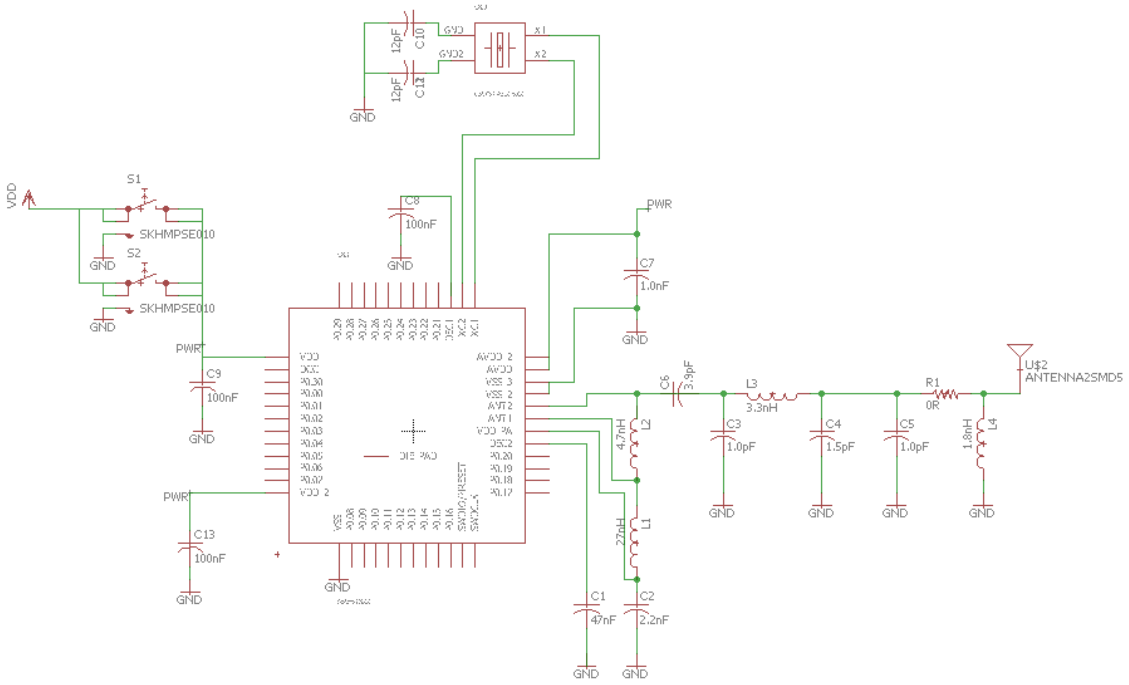


Figure 48: Device 1 Schematic

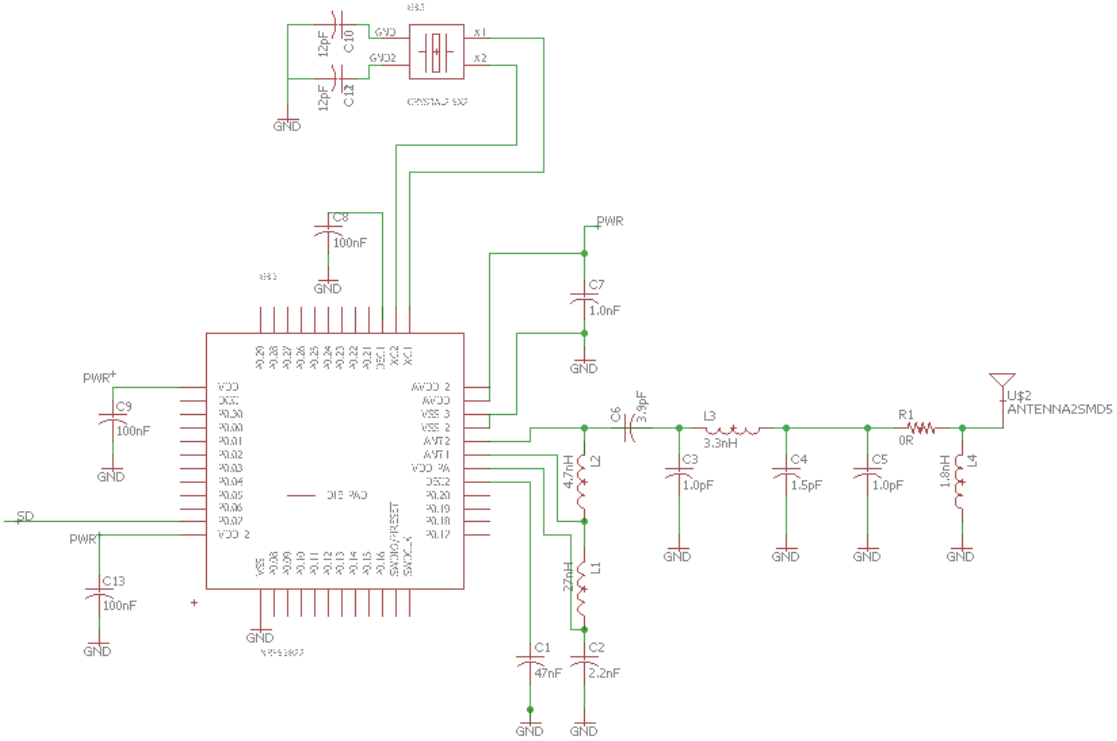


Figure 49: Device 2 Radio Schematic

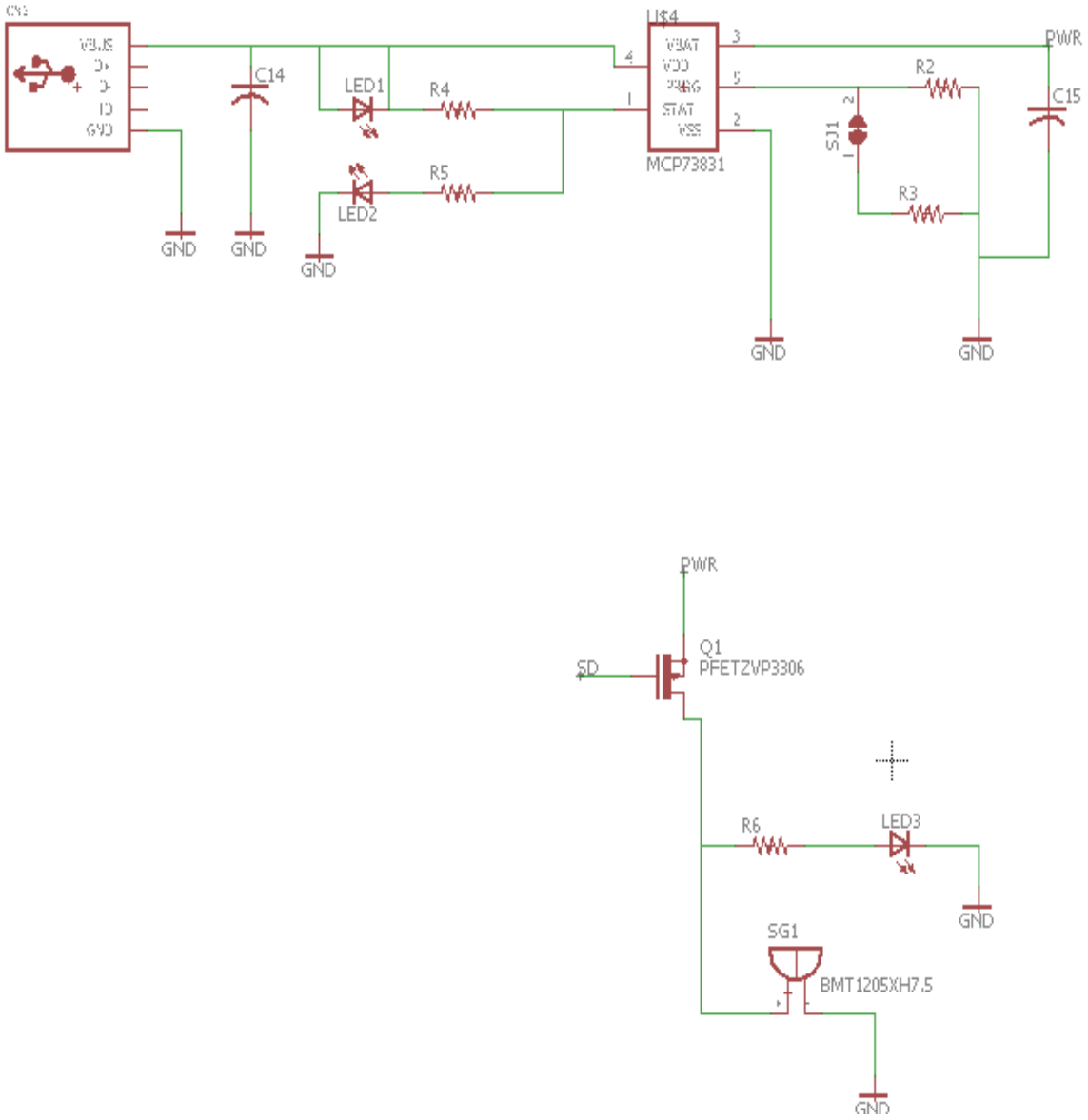


Figure 50: Device 2 Charging Circuit and Defense Circuit Schematic

Shown above are all of the schematics for the two devices. Device one is the simpler of the two needing only two switches attached to the power connections of the radio chip, as well as access to the pins needed for programming of the chip. All other pins on the microcontroller will be grounded as none will need to be used in the particular design. Both devices use a similar set up for the radio of the chip as both use the same chip and will work at the same frequency. The second device will have access to several pins for data pins, with pin 1 going to a MOSFET that will allow power from the source to power the circuitry in the self-defense device to power the components with the required voltage.

# 6.3 PCB Venders

A few things have to be considered when selecting a vender our PCB. One main concern for the selection of our vender is that the PCB will be to be populated for a portion of the board as there is limited access to a reflow oven that would be needed for non-leaded components such as out microcontroller chips that are 48 pin QFN (Quad Flat No-lead). Other small surface mount devices would need to be populated on the board as well to ensure proper placement. Larger surface mount components and through hole components can be populated by group which can help keep the costs down. Another main concern is the overall cost for the boards to be created.  Estimated costs for both fabrication and assembly are shown below:

| **PCB Vender** | **Qty** | **Price** | **Lead-time** |
|---|---|---|---|
| Advanced Circuits | 4 | $182.00<br>($45.50 each) | 10 Days |
| Bittele | 3 | $163.61<br>($54.54 each) | 5 Days |
| PCB Cart | 5 | $23.75<br>(4.75 each) | 9 Days |
| Accutrace | 3 | $190.00<br>($63.33 each) | 11 Days |

Table 13: PCB Fabrication Costs

| Company | Qty | Prices | | |
|---|---|---|---|---|
| Advanced Circuits (4PCB)<br>USA<br>★★★★☆<br>Read or write reviews | 6 | 10 days:<br>5 days:<br>2 days: | $220.56 total<br>$286.68 total<br>$396.96 total | ($36.76 / board)<br>($47.78 / board)<br>($66.16 / board) |
| Bittele (7pcb)<br>Canada<br>★★★★☆<br>Read or write reviews<br>*Use the Prototype service* | 6 | 5 days:<br>2 days: | $277.18 total<br>$360.33 total | ($46.20 / board)<br>($60.05 / board) |
| PCBCART<br>China<br>★★★★★<br>Read or write reviews<br>Go to Order Page | 6 | | $339.00 total | ($56.50 / board) |
| PCB Assembly Express<br>USA<br>No reviews yet<br>Read or write reviews | 6 | 10 days:<br>5 days:<br>3 days:<br>2 days:<br>1 day: | $421.98 total<br>$493.98 total<br>$541.98 total<br>$619.98 total<br>$739.98 total | ($70.33 / board)<br>($82.33 / board)<br>($90.33 / board)<br>($103.33 / board)<br>($123.33 / board) |
| Accutrace PCB4U<br>USA<br>★★★★½<br>Read or write reviews | 6 | 30 days:<br>20 days:<br>15 days:<br>10 days:<br>5 days:<br>3 days: | $533.98 total<br>$541.96 total<br>$550.00 total<br>$574.00 total<br>$589.96 total<br>$637.00 total | ($89.00 / board)<br>($90.33 / board)<br>($91.67 / board)<br>($95.67 / board)<br>($98.33 / board)<br>($106.17 / board) |

Prices do not include PCB fabrication or the cost of components.

Figure 51: Estimated Costs for Population of Boards

The only PCB fabrication venders that were considered were ones that also were able to populate the board. All of the quotes are estimates based on the approximate size of the board and how many pieces will need to be populated onto the board. Although the population price for the boards is least at advanced circuits, the price for the board is forty-five dollars each, or thirty-three with a student plan. This would price the cost per board to over sixty-six dollars while the price per board at PCB cart is estimated at just over sixty-one dollars a board. This price does not include the cost for shipping which may also effect the final description for which PCB vender to purchase the final boards.

An advantage to the vender PCB CART is that it will make 5 boards for the cheap price which will allow for more back-up boards in case one board does not work. Increasing the amount of boards for population would also decrease the overall cost per board, reducing the final costs further. PCB Cart also provides a

guarantee for the boards and are generally reviewed well. While other venders can offer similar advantages, it is good to know that these are offered by the vender what was selected for its lowest priced option out of all of the venders with population of the board abilities.

# 6.4 Final Coding Plan

## Device 1 and Device 2 Firmware

The development of the firmware for Device 1 and Device 2 will use the nRF51 SDK provided by Nordic Semiconductor along with the open source GNU ARM Embedded Toolchain, which allows the GCC compiler to cross-compile for the ARM Cortex M0 from Windows, Mac OS, or Linux hosts. Because cross-compilation is necessary, an IDE will not be used, with a text editor with C language syntax highlighting in its place. Due to the feature simplicity and embedded operating environment limitations, a structured programming model will be used, while a spiral-shaped development cycle to regularly produce versions meeting the latest requirements as determined by testing of successive prototypes.

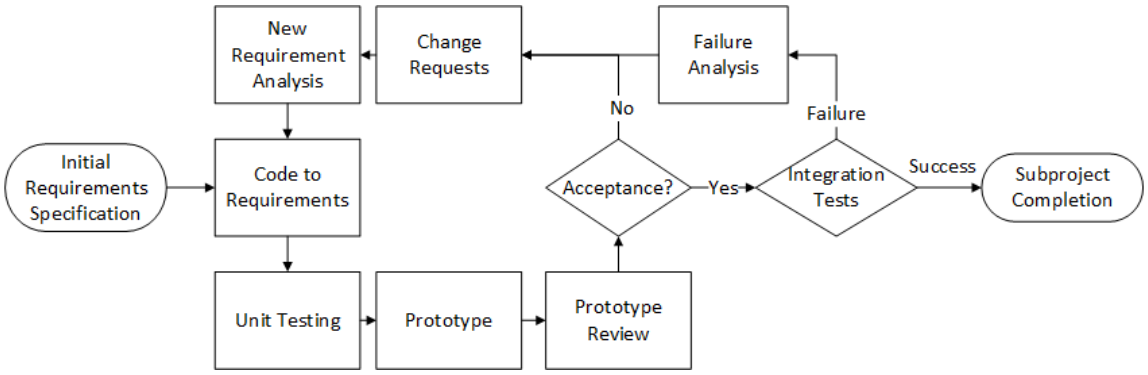


Figure 52: Device 1 and Device 2 Firmware Development Cycle (Spiral)

## Mobile Application

### API Level:

The application program interface(API) is a set of routines, protocols, and tools for building software applications. Each API is broken down into a certain level, or an integer that uniquely identifies the framework API revision offered by a version of the Android platform. Each platform provides a framework that applications can use to interact with in the Android system, consisting of a core set of packages and classes, Extensible Markup Language(XML) elements and attributes for declaring

files and resources, intents, and permissions that applications can request from the user. As parts of the API are upgraded, the older parts will only deteriorate, not removed, therefore allowing applications using older API levels to continue to use them. These API levels can be established upon making a new project, and can allow for the minimum and maximum API levels to be established in the manifest file. The newest API level is API level 24, or Android 7.0 Nougat, which is only available to certain Nexus models and other Android phones. This update comes with improved battery life, revamped notifications and settings menu, and other features. This application will be using the 21st API level, which is the Android 5.0, or Lollipop. Android 5.0 comes with a variety of new and improved features, such as android TV, advanced connectivity, enhanced video and camera, and a new material design for an expanded UI toolkit. We chose the 21st API level because while also trying to keep relevantly new software, we didn't want to exclusively set it where only a certain number of people can use it. As seen in the figure below, the chart represents the distribution of people using a certain API level. We wanted to have a lot of people to be able to use our application as well as keep the software relatively new, which led to the choosing of API level 21, with about 41% of people using at least this API level.

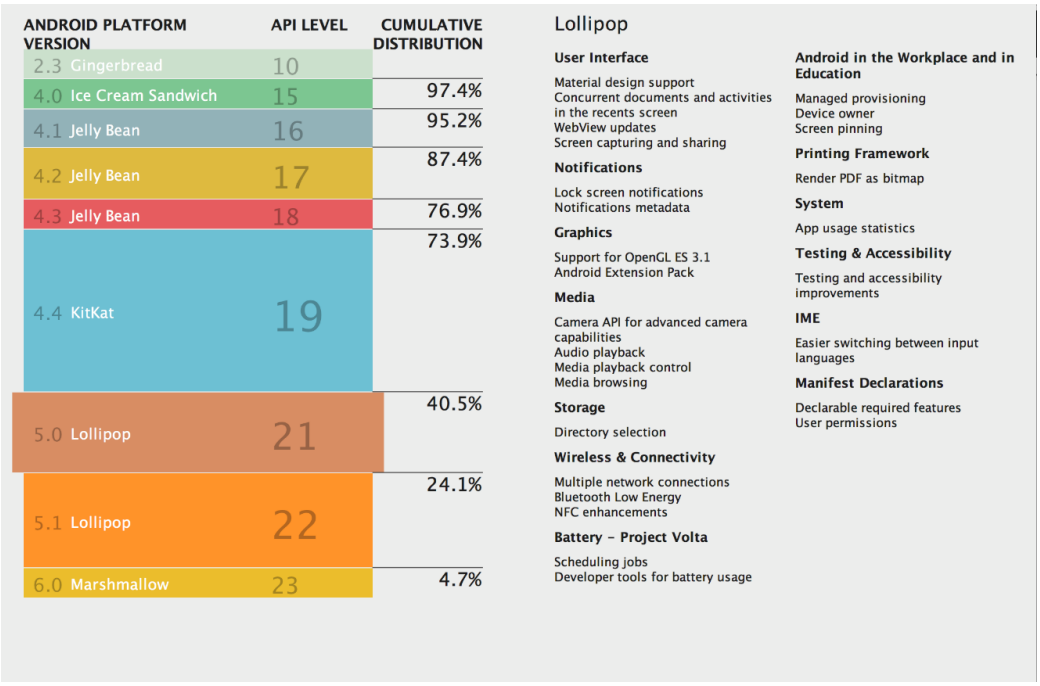


Figure 53: API Level Chart

## Permissions:

To access certain features for this application, a permission must be made into the android manifest file of the app. A permission is a restriction that limits access to a part of the code on the device. Using permissions will filter out all phones that have access to the google play store that don't necessarily meet all of the specific requirements. The requirements that are needed with this phone include Bluetooth capabilities, camera access, and location services. As such the following permissions are required in order to have full access of this application. Camera access must be allowed, access to the phone's image gallery, Bluetooth capabilities must be allowed, and location services must be allowed in order for the user to download this application.

## User Interface:

This app was made with a simple design in mind in order to let the user have an easy way to navigate the interface. Colors based around UCF were made since KnightGuard is an affiliate of UCF. The main points of the app that will be discussed will be the camera, Bluetooth, GPS, authentication, and database.

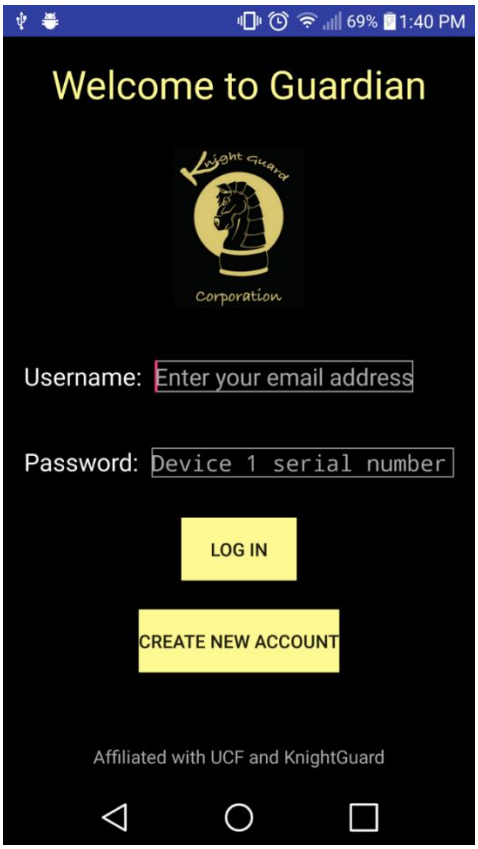


Figure 54: Application Login

The first page will serve as the login page, where the user will input their information to login, or will create a new account. If creating a new account, the credentials needed by the user will the following along with others: the user's first and last name, date of birth, height, weight, eye and hair color, username, password, and picture. Our idea for the username is an email address and the password is the serial number that comes with the device 1. A picture will be needed so the police have a general description of what the user looks like. Users can either take a new photo or use a pre-existing one that is stored already on the phone's gallery. When the account has been created, you will be asked to enter a code for validation purposes, which can be found by going into the email that was given as the username. You will only have 30 minutes to enter the code before it expires. When the correct code is entered, you will be able to pair up your mobile device with device 1 through Bluetooth. Now logged in, users will have the opportunity to test their last known GPS location, change settings, and other features. When the application detects the signal from device 1, a signal will be sent to a police station near you, and will send them the information that was entered when initially put in. They will see they basic information in one corner, a picture of user in another corner, and the GPS location of the last known location the phone picked up on the other half of the screen. Figure 3 shows a similar design in which we plan to implement this. When the signal is being sent to the police, a quick sound would be put out to disorient the attacker. When the police have apprehended the attacker, the user must press the stop button to turn off the sound and the phone app will then be put on standby mode.

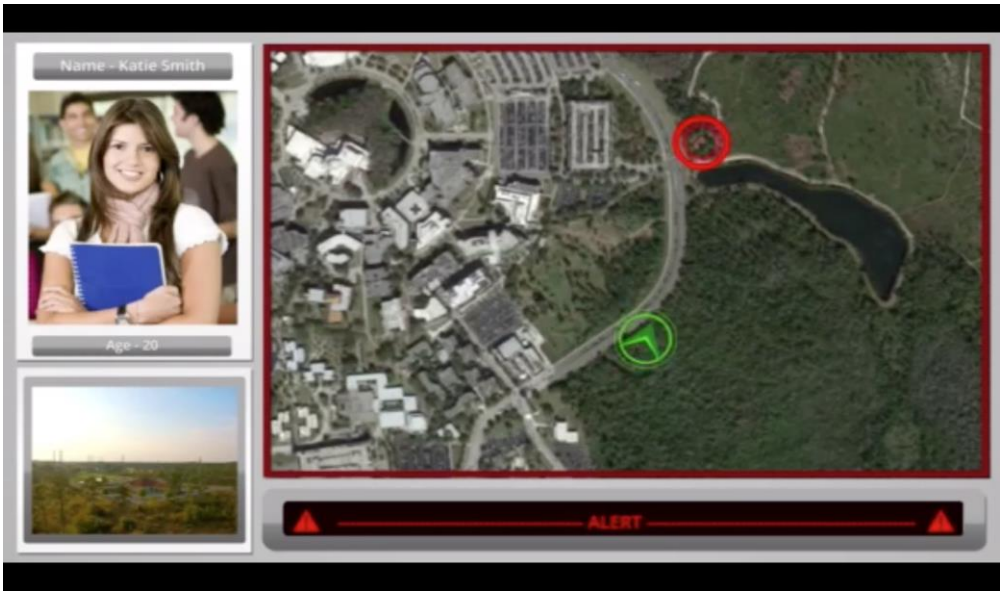


Figure 55: General Idea of Emergency Interface

## Accessing the Camera:

The camera will be taking 2 different activities in its 1 page, one where a picture is taken from the phone's built in camera, and the other to access a photo from the built in photo gallery. To begin either procedure, a permission must be made in order to access both the camera and the photo gallery. To access other applications that are already on the mobile device, the use of an Intent will be used to invoke the existing camera application built in. To work this process, there are parts to invoke it: the actual Intent, a call to start the activity, and code to hold the data when coming back to the application. The startActivityForResult () method will be used to start the activity. To differentiate between picking the new picture button and the existing picture button, the result will be looking for either a 0 or a 1, with the 0 representing the new picture button, and the 1 as existing picture. When the value is returned, the picture will then be loaded into the image view. Figure 19 gives a flowchart of the general idea of the process that is taking place.

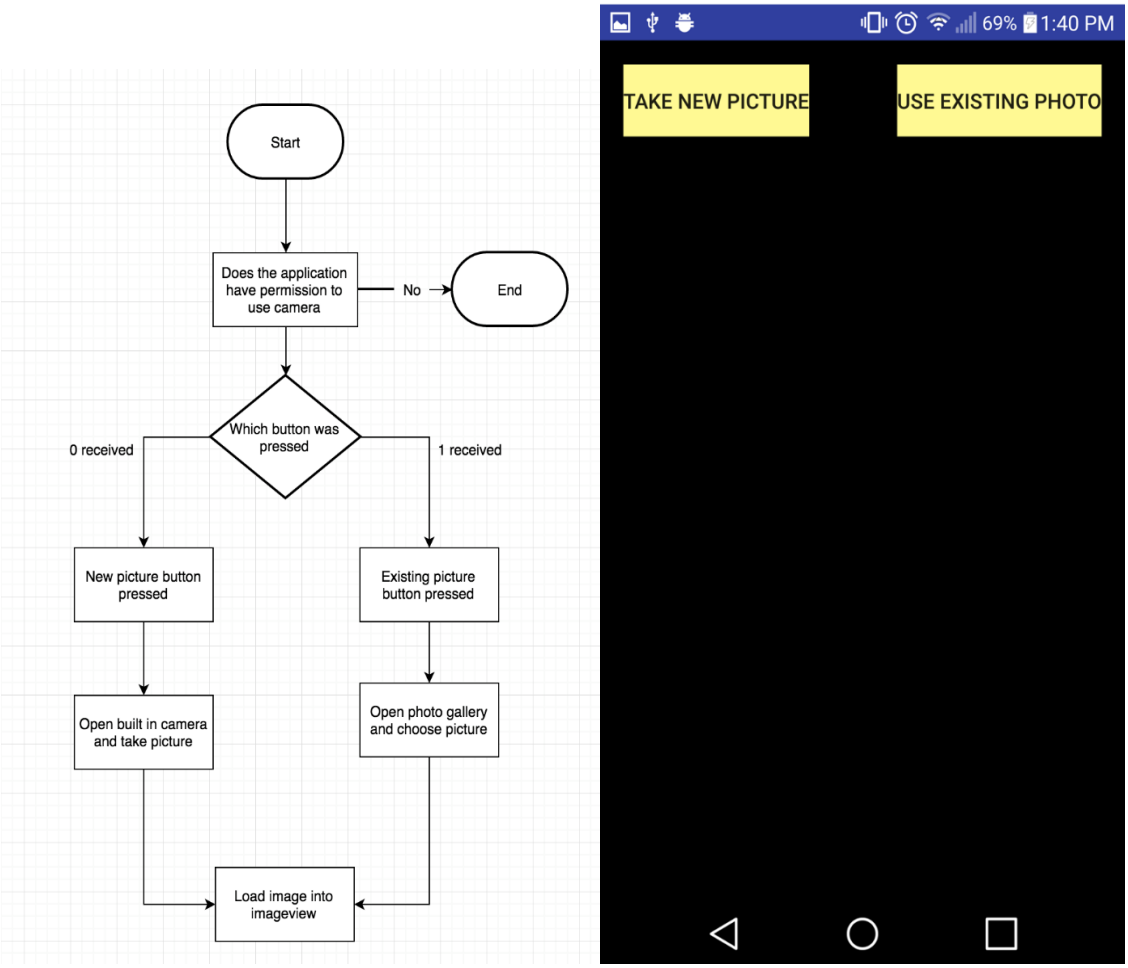


Figure 56: Camera Flowchart and User Interface

## Connecting Devices through Bluetooth:

We will need the first 2 devices to connect with this mobile device in order to work effectively. In order to do this, start by getting the permission to perform any type of Bluetooth communication. Next, a verification of Bluetooth needs to be done to see if Bluetooth is supported on the device and if so, enable Bluetooth on the device. This process can be done by using the Bluetooth Adapter method, which will let the user perform easy Bluetooth tasks. After enabling, the device then needs to find remote Bluetooth devices, which can be done by either querying paired devices or discovering devices. It is recommended to query the paired list first to check if the device is already paired with the phone. When the remote device is found, a connection must be established to link the 2 devices together, either as opening a server socket, or initiating a connection as a client. When a connection has been established, each device will have a connected Bluetooth Socket, which can allow you to share data between both devices.

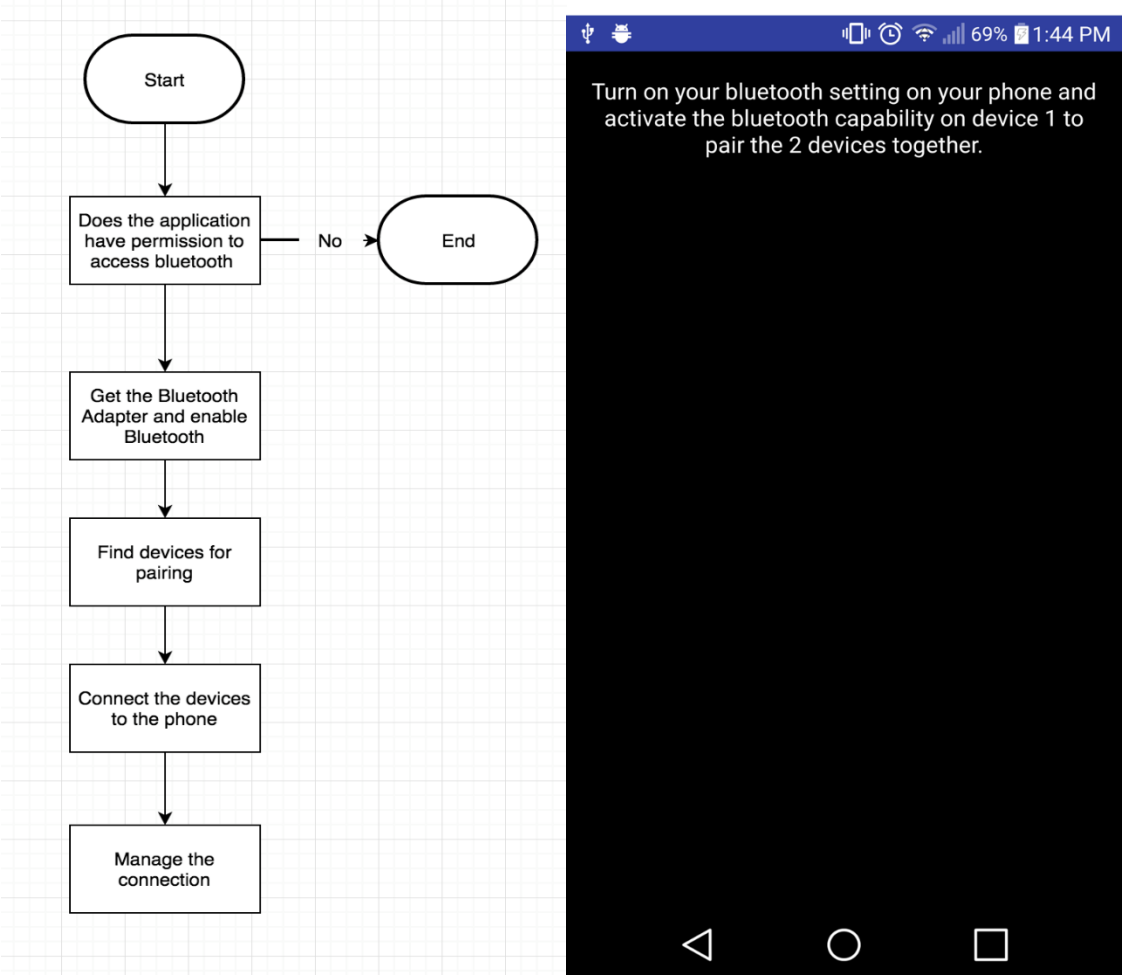


Figure 57:Bluetooth Flowchart and User interface

## GPS Tracking:

We also will provide the ability to track your current location, whether the user is in distress or not. To start this, again the device must have permission to access the phone's location services. If so, indicate that you would like to receive location updates from the LocationManager. Now, you want the device to start listening for location updates as soon as the current location button is pressed. Often when the first location is received, it takes too long for the user, so use a cached location to keep the last known location. Then, it should stop listening for updates to save battery power, so as soon as the information is collected, stop listening for updates. Finally, cases need to be to ensure the best location, whether it be if the new location is significantly newer than the old one, or if the accuracy found is better or worse than the previous estimate.

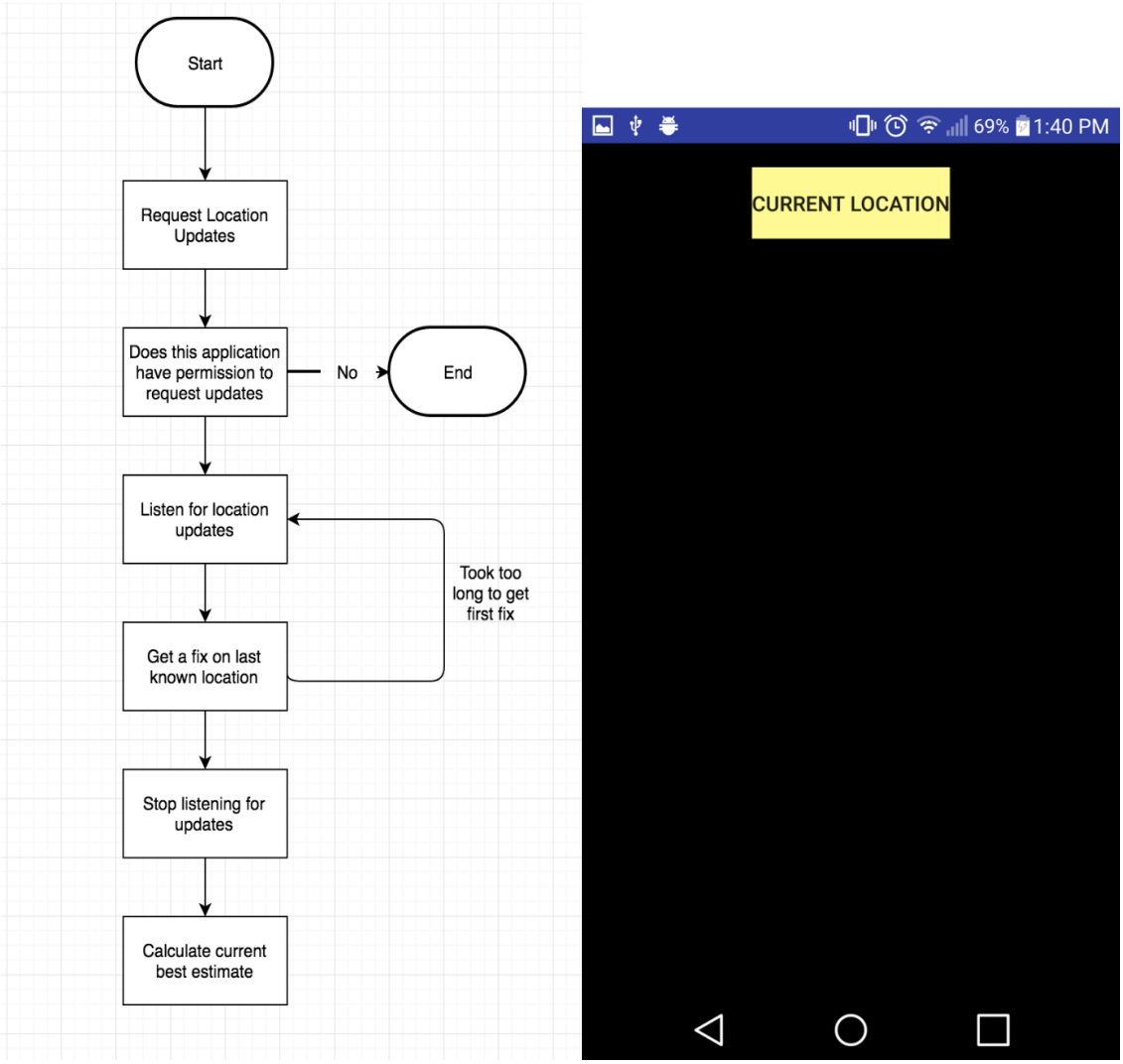


Figure 58: GPS Flowchart and Interface

## Input the Information into Mobile Application Database:

When all the information is inputted into the required fields, said information will then be sent out to a database. In order to do this, first start out by creating a schema, a formal declaration of how the database is organized, and a contract, a container for constants that define names for URIs, tables, and columns. Now that the database has been defined, next is to create and maintain the database and tables. This database will be stored in private disk space and not accessible by other applications. To put data into the database, pass a ContentValues object in the insert() method. When the data needs to be read, the query() method must be used, where you pass your selection criteria and desired columns. The query will then return your results as a Cursor object. When needed to, such as updating the age of the user or if the user gets married and changes their last name, updating columns can be done by using the update() method.


Figure 59: Sign-up User Interface

With the user information stored in the mobile application database, it is ready to be formatted for upload to the web server. A new JSONObject is instantiated as an extension of the Map class and the user data is inserted using the Map.put(key, value) method, with the type-appropriate Cursor.get*() method for value. A TLS secure connection to the web server is established and verified using an HttpsURLConnection object, and the JSONObject is then uploaded using an HTTP POST request. The database information as seen by the mobile application is illustrated below.

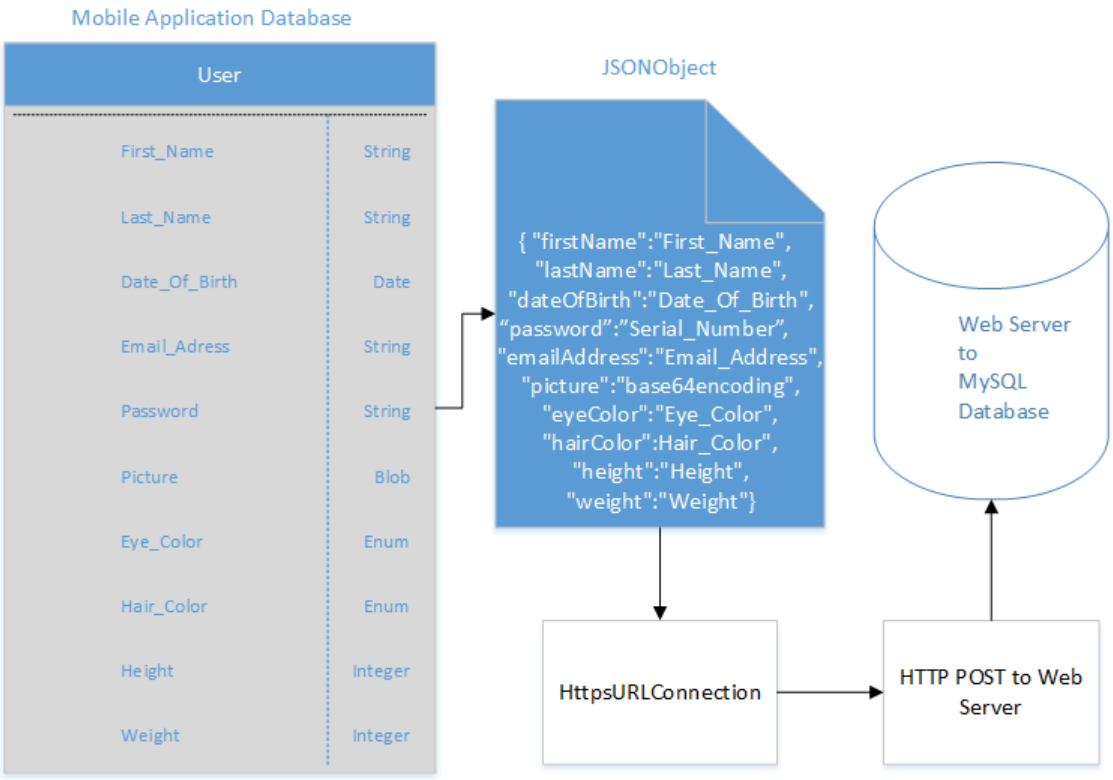


Figure 60: Mobile Application Data Transfer as JSON Object

# Web Application

Development of the web application will require an available installation of a web browser, a web server with a PHP interpreter, and MySQL database. The development workstation, running a special configuration of the Gentoo Linux operating system, will use a local instance of Apache and MySQL to closely mirror the LAMP stack that will be used in the demonstration production server, and the Chromium web browser, identical for our intents and purposes by way of shared source code to the Google Chrome browser used in the frontend workstation. The Netbeans IDE, rejected for use in the development of the mobile application due to complexity, is available in a streamlined configuration for PHP development, integrating the local LAMP stack for initial development

testing, and includes the ability to upload code directly to the production server using SFTP, as well as support for remote version control systems for team-based development. Programming will be based on the Document Object Model for the HTML and CSS components, Object Oriented for PHP and database components, and event driven for JavaScript and Ajax components. A waterfall development model will be used to produce the fully-functional system efficiently with no accommodation for changes in the requirements, to prevent any delay that may be caused by scope creep.

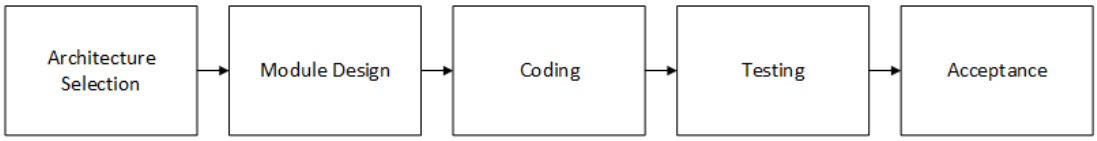


Figure 61: Web Application Development Cycle (Waterfall)

## Distributed Version Control using Git and Visual Studio Team Services

Coordination of team-based software development is greatly enhanced through the use of distributed version control, such as through the Git version control system. Each developer on this project will maintain a local Git repository to track all changes he makes to the source code from inception to completion, synchronizing with a central server in the Visual Studio Team Services cloud service. Upon completion of a key feature, bug fix, or other opportune moment, the other developer will perform a code review, verifying that the software works as intended, and merging the finalized changes into the main development branch. Further work units will be performed on new forks off of the main branch, again to be merged back into the main once the unit of progress has been made, or else abandoned and restarted from a known good branching point. The use of delta files by Git to track changes means that branching from even large code bases is only a matter of storing the small amount of code that has changed from version to version, and allows the use of simple text-based reconciliation software to perform merges.

Above the benefits of distributed version control provided by the Visual Studio Team services implementation of Git are several project management features, such as the ability to assign work breakdown structure units to individual team members, generate lists of manual testing to-do lists from development requirements entered as user stories, execute automated build scripts, and generate charts to supplement progress reporting. These features will allow the sponsor to monitor the status of the software components of the project and direct workflow corrections wherever needed.

# VII. Prototype Testing Plan

## 7.1: Component Testing

As the primary components are acquired, tests are performed for their functionality. All of the tests performed for the components of device one and device two were done in a lab with access to function generators to apply input signals and to view how specific components reacted with turning on and off constantly. A challenge in testing the device, is that many of the labs available for testing are open to other students in the engineering department. This required the testing to be done in early morning and late night to maintain the secrecy of the design. Other tests, such as the hardware using for power, could be done in any location as it only required a power source, and a timer

### Battery testing:

Tests for the battery were performed using the LiPo battery as it is the battery that will not be replaceable. The test done was to find the max charging time. To ensure that the batteries were fully discharged prior to testing the charge time, the battery was placed over a resistor that slowly dissipated the power in the battery. Once no voltage was detected by a multimeter, the battery was moved to that charging circuit. Using an Adafruit 100mA LiPo charging circuit that the final charging design of the PCB will be based on, the battery was placed on charge and checked at five minute intervals for completed charging. Over several tests, the charge was completed between forty and forty-five minutes. Charging speed could be increased by increasing the current, which is done by shorting two pads on the charging circuit that would increase the current to 500mA, but could risk the heating of the battery, risking the integrity of the battery and the safety of those testing the device. As the self defense mechanism is still in development exact current measurements could not be made. However, all components selected have a low current draw, with device one having a max current of 13mA when the chip is activated to send a signal over Bluetooth.

### Switch Testing

Both a push button switch and a two-point switch were tested to make sure power could only pass through when the switches were activated. The push button which will be used in device one is designed to be off or on, and the two-point switch can be designed with multiple inputs, but was made to be off and on by shorting the first and second pins of the switch. Both of these were done using the LiPo battery and a resistor. A multimeter was set up over the resistor and the switches were placed between the battery and the resistor. The testing showed one percent of

the voltage over the resistor when the switch was activated and no voltage when the switches were off, ensuring the devices functionality.

## Buzzer Testing

The buzzer was tested for pitch as well as ability to hear the device within the specifies range. This test was achieved by attaching the buzzer to a proto-board and applying a square wave from the function generator on the pads, to simulate turning on and off of the device. The pitch heard from testing was the same as the one created through a tone generator. For checking that the device could be heard within a range of four feet, the device was placed in the same function generator circuit and another member of the team walked away from the device. It was able to be heard at the distance needed, but quickly seemed to drop off after softly after, becoming harder to hear.

## Chip Testing

The primary purpose of the testing of the chip is to ensure that the chip will be able to provide a signal to the output pins properly with the given batteries providing power to the chips. The chip will be tested using a nRF51 development kit which can be programmed using an Arduino protocol or ARM just as the final chip. Both batteries were able to provide sufficient power to allow the chip to work. As the Bluetooth functionality had not yet been achieved by the application, further testing on signal strength and range of the chip will be determined in future tests with the PCB design as the antenna will be smaller in the final design, shortening the range to only allow for the short range communication.


Figure 62: Nordic Development Kit

The picture above is of the development kit that allows the group to use Arduino coding and ARM to program the NORDIC microcontroller and the Bluetooth chip that will be used in device 1 and device 2.

# 7.2 Software Test Environment

## Device 1 and 2 Firmware

The first stage of testing of the firmware for Device 1 and 2 consist of unit tests of the software as executed by the ARM Fixed Virtual Platform (FVP) corresponding to the ARM Cortex M0 CPU of the selected nRF5182 chip. ARM Holdings provides both a Linux-hosted and Windows-hosted version of this FVP as a free download for registered users at the ARM Developers website. Intended for developers who do not have a physical target device, FVPs provide a fully modeled simulation of device processors, memory, and peripherals. By first testing on virtual hardware, faults found at this stage can be corrected on the developer workstation without expending flash erase cycles. [41]

The second through fourth stages will access the on-chip debugging capability of the nRF5192 using a USB developer board to trace execution. The second stage will consist the same unit tests performed on the FVP, while integration testing of the software for each device will begin using a software simulation of the other and the mobile device. The fourth stage will use two nRF59192 chips and an Android device to test the Bluetooth communication of each device. The final stage of integration testing will be performed once the microcontroller chips have been mounted their respective prototype device boards and field tests begin in conjunction with the mobile device application and the web application.

## Mobile Device:

When done with making any changes, there are 2 ways to run this app, either a real phone or use an emulator. To use your phone, simply plug in the USB cable into the computer and connect it to your phone. When plugged in, USB debugging needs to be enabled by going into your developer options. If developer options are hidden, then go to about phone, and tap build number 7 times to make it appear. Go back to Android Studio, run the project, and the select deployment target window will pop up where you can select your device. The app will automatically install the app on your phone and immediately open the app. When using the emulator, an Android Virtual Device(AVD) must be created. To make one, open up the manager, create a new virtual device, select a hardware phone device, download a system image to recreate the API on the emulator, and make any other necessary changes you need. Same rules apply as a real device when running the project. When the app is run, check all features to make sure that they are running

properly. [15] Features that will be extensively tested include the camera, where we will check the image resolution, safely storing the picture into the phone's built in photo gallery, the ability to pull an image from the photo gallery successfully, and checking if the picture successfully was stored in the database. Another feature tested will include the GPS tracker, where we will test whether the correct coordinates are being displayed in different locations, how soon the coordinates come back to the app, and can these coordinates can be used when the police are tracking the phone. Bluetooth capabilities will also be tested by seeing if more than 1 device can be paired, and if so, can the maximum number of 8 devices can be paired, the time it takes to connect the devices, and how long it takes for the signal to reach the phone from device 1.

## Three-Tier Web Application

The server and database tiers of the web application will be first tested on the developer workstation using locally hosted instances of both the WAMP stack and LAMP stacks by installing the Apache web server, MySQL database management system, and PHP interpreter in both Windows and Linux environments in a dual-booting manner. Test cases at this stage will utilize simulations of the web browser front-end and the mobile application. Upon completion of the local stage of testing, the code will be uploaded to a web-facing staging server that uses the same platform as the eventual production server and the same unit tests will be carried out. Initial testing of the frontend web pages will be tested on the developer workstation using complementary simulation of the server components, testing against the latest versions of the Microsoft Internet Explorer, Microsoft Edge, Google Chrome, and Mozilla Firefox browsers. Testing of the Apple Safari browser will be forgone at this stage due to the discontinuation of the Windows version of the browser and the lack of a Linux version.

Internal integration testing of the three-tier web application will begin on the development workstation by testing all use cases of the web-browser frontends in each of the previously listed browsers and simulations of all use cases of the mobile application. The front-end source code would then be uploaded to the staging server and the same tests will be carried out, with the addition of the Apple Safari browser on a publicly usable Apple Macintosh computer.

## Software Full Integration Testing Environment

The system integration testing can begin once all three projects have completed their internal integration tests. The Device 1 and 2 firmware tests require completion of hardware components and the web application depends on the provisioning of a web-exposed server and acquisition of a TLS certificate, while the mobile application has no timing factors besides the development of the

software itself. Otherwise, the laboratory and field testing locations described in section 7.1 can be used given that sufficient diagnostic logging of the server and mobile components have been enabled.

# 7.3 Software Specific Testing

## Device 1 Firmware Test Cases

The Device 1 firmware will be tested against the following input scenarios. Software stand-ins for other devices will be used until integration testing begins.

| **Input Scenario** | **Pass Criteria** |
|---|---|
| 1. Activation input deasserted for continuous 2000 ms | Device remains in low-power mode for duration of the input scenario |
| 2. Activation input asserted for less than 10 ms, deasserted for 1000 ms before and after | Device leaves low-power mode but Bluetooth connection routine is not started and low-power mode is resumed |
| 3. Activation input is continuously asserted for more than 10 ms but is deasserted within 300 ms for 1000 ms after and 1000 ms before | Bluetooth connection routine is started and connects to dummy Device 2 but transmits cancellation signal and low-power mode is resumed |
| 4. Activation input is asserted continuously for more than 300 ms | Bluetooth connection routine is started and connects to Device 2 transmits confirmation code at 300 ms, and connects to Android device, transmitting distress code |
| 5a. Activation input is asserted continuously for more than 300 ms but Device 2 connection times out<br><br>5b. Activation input is asserted continuously for more than 300 ms but Android device times out | Bluetooth connection routine is retried continuously once activation input is asserted |
| 6a. Activation input is asserted continuously but Device 2 connection | Bluetooth connection routine is started and connects to Device 2 and Android |

| | |
|---|---|
| times out until connection is successful after 300 ms of activation<br><br>6b. Activation input is asserted continuously but Android device times out until connection is successful after 300 ms of activation | device and transmits confirmation code immediately |

Table 14: Device 1 Test Cases

## Device 2 Firmware Test Cases

The Device 2 firmware will be tested against the following input scenarios. Software stand-ins for other devices will be used until integration testing begins.

| **Input Scenario** | **Pass Criteria** |
|---|---|
| 1. No Bluetooth connection attempt is made for continuous 30 seconds | Device stays in low power mode |
| 2. Bluetooth connection attempt matching pairing codes of Device 1 is received | Device establishes connection within 10 ms |
| 3. Confirmation code is received from Device 1 | Deterrent triggering output is asserted within 10 ms |
| 4. Cancellation code is received from Device 1, and connection is not reestablished after 30 seconds | Device remains in active mode for 30 seconds, then returns to low power mode |
| 5. Cancellation code is received from device 1 but connection is reestablished within 30 seconds | Connection reestablishment latency is less than 10 ms |

Table 15: Device 2 Test

## Mobile Application Test Cases

The mobile application will be tested against the following input scenarios, using stubs in place of Device 1 and the web application for unit testing until integration testing begins.

| Input Scenario | Pass Criteria |
|---|---|
| **1. User inputs invalid data in a registration field, one subcase per field** | Input validation failure message is shown to user |
| **2. User inputs valid data in all registration fields and submits** | Properly formatted and encrypted message is sent to Web Application |
| **3a. Device 1 sends confirmation signal while application is open**<br>**3b. Device 1 sends confirmation signal while another application is open**<br>**3c. Device 1 sends confirmation signal while device is locked**<br>**4. In-app distress button is activated** | Distress call routine is successfully invoked |
| **5a. Distress call routine is invoked; location services are disabled** | Properly formatted and encrypted message is sent to Web Application with user identity and NULL geoposition<br>Message requesting activation of location services presented on screen. |
| **5b. Distress call routine is invoked; location services were disabled but then enabled by user**<br>**5c. Distress call routine is invoked, location services enabled** | Properly formatted and encrypted update messages with user identity and best available geoposition are sent to Web application until maximum precision is achieved |
| **6. web application signals call received** | SIP session established. Speakerphone set to on and plays demonstration stream followed by delayed echoes to demonstrate microphone functionality |

Table 16: Mobile Application Test

## Web Application Front-end Test Cases

The front-end of the web application will be tested using the following scenarios. Stubs will first be used in place of the mobile application and the back-end, then the web application integration test will combine these criteria with the criteria for the back end, and then final integration testing will proceed.

| Input Scenario | Pass Criteria |
|---|---|
| **1a. Front-end is accessed without existence of document cookie**<br>**1b. Front-end is accessed with cookie indicating "Do Not Show This Message Again" was not selected at the last run** | Message displayed indicating workstation requirements: properly configured audio devices and sleep timer and screensaver disabled |
| **2. 60 Continuous minutes with no distress call** | Layout has been cycled twelve times in standby to prevent burn-in risk |
| **3a. Distress mode activated by server , missing information**<br>**3b. Distress mode activated by server full information included** | Display switches to alert mode<br>Alarm is sounded, all available information is shown on display; information that is missing is clearly indicated as such<br>SIP session initiated with Mobile Device, workstation microphone is muted |
| **4a. Display is in alert mode, Mobile Device geoposition is not NULL**<br>**4b. Display is in alert mode, Mobile Device geoposition has changed** | Latest mobile device geoposition is indicated on map, retained when map is panned or zoomed |
| **5. Display is in alert mode, operator has acknowledged the alert** | Alarm sound ends, workstation microphone is unmuted |
| **6. Display is in alert mode, operator has not cancelled the alert for duration of test** | Display remains in alert mode for full duration of test |

| | |
|---|---|
| **7. Display is in alert mode, server indicates another distress call is received** | Passing criteria for scenarios 3-5 with additional color coding and SIP session switchboard displayed |
| **8. Display is in alert mode, operator cancels all alerts** | Display returns to standby. |

Table 17:Web Based Test

## Web Application Back-end Test Cases

The back-end of the web application will be tested using the following scenarios. Stubs will first be used in place of the mobile application and the front-end, then the web application integration test will combine these criteria with the criteria for the front end, and then final integration testing will proceed.

| Input Scenario | Pass Criteria |
|---|---|
| **1. Invalid registration data is received from Mobile Application.**<br>**2. Invalid confirmation code is received from Mobile Application.**<br>**3. Confirmation code is expired.** | Report registration failure to Mobile Application |
| **4. Valid registration data is received from Mobile Application** | User information inserted into database; confirmation email is sent |
| **5. Valid email confirmation code is received from Mobile Application** | Update user row in table USERS with verification bit |
| **6. Distress call is received from mobile application** | SELECT name, date-of-birth, photo, height, weight, hair color from table Users; encode along with geolocation if not NULL and send to front-end. Negotiate SIP session between front-end and mobile application |
| **7. Additional updates from mobile application are received** | Update front-end with latest geoposition |

Table 18: Web Back-end Testing

## Integration Testing Sequence

1. Device 1 and 2 Integration
    a. Establish Bluetooth pairing between Device 1 and Device 2.
    b. Demonstrate that activation of Device 1 according to unit tests results in the activation of Device 2 in accordance with unit test criteria
2. Mobile Application and Web Application Integration
    a. Successfully register new user in accordance with unit tests; verify by using super user access to query the USER table directly
    b. Successfully activate distress signal on Web Application frontend using criteria from unit tests and added criterion that geolocation be displayed accurate to 7.8 meters
3. Full System Integration, Acceptance Test, and Demonstration
    a. Demonstrate that activation of Device 1 according to unit tests results in success as defined in Integration Testing 2-b.

The full testing sequence with necessary prerequisites to each test is displayed in the flowchart below.

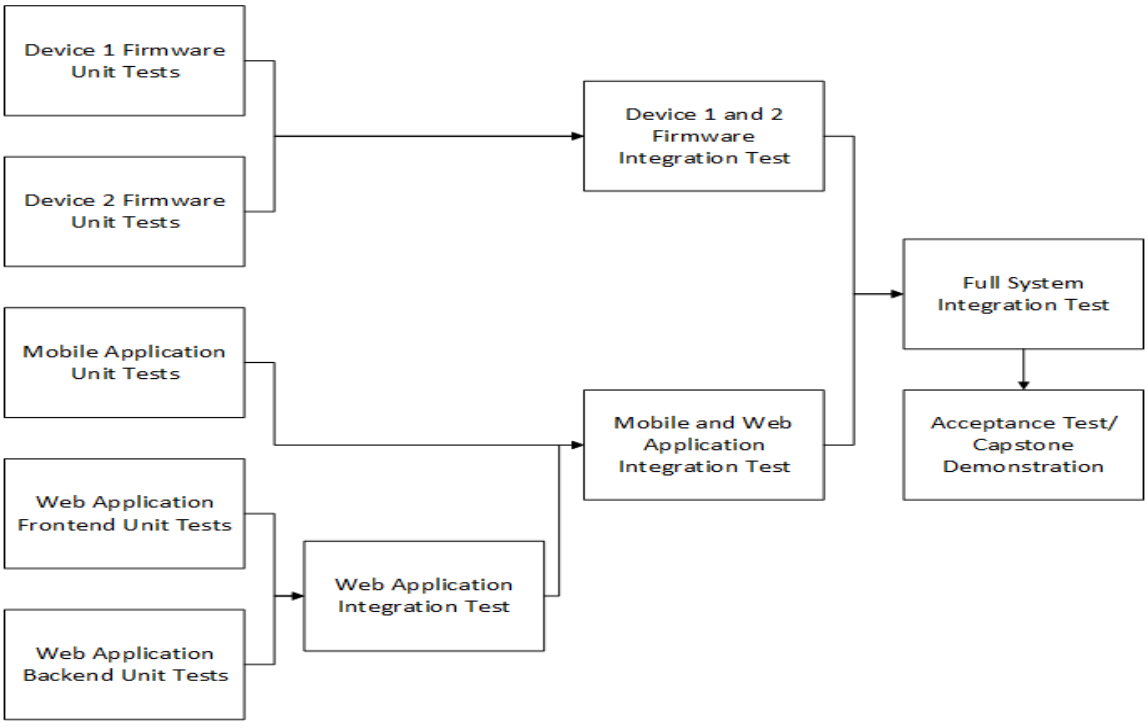


Figure 63: Full Software Testing Sequence

# VIII. Administrative Content

## 8.1 Milestone Discussion

| | Device 1 | Device 2 | Phone App | Communication/Signaling |
|---|---|---|---|---|
| **Main** | **Dominic** | **Matthew** | **Brandon** | **Ralph** |
| **Backup** | **Matthew** | **Dominic** | **Ralph** | **Brandon** |

Table 19: Project Responsibilities Division

**Timeline:**

The following tables represent the timetable of each components as they are completed broken down into the number of weeks it took to complete them and the month/months it took place.

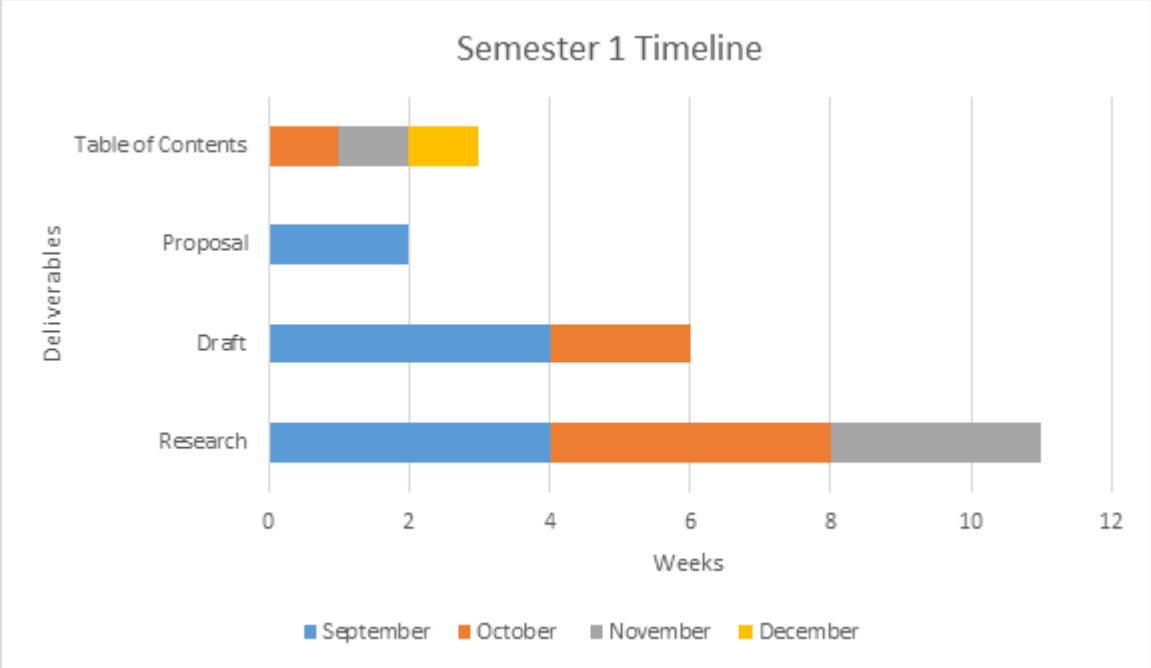


Figure 64: Chart of Timeline in Semester 1 Part A

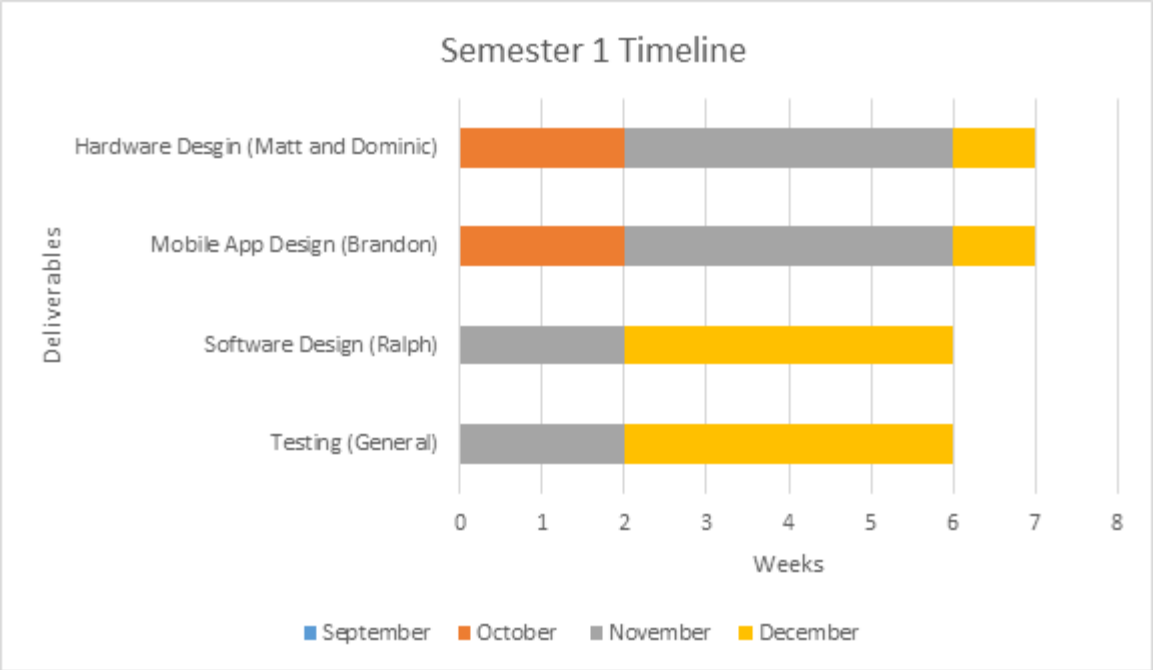


Figure 65: Chart of Timeline in Semester 1 Part B

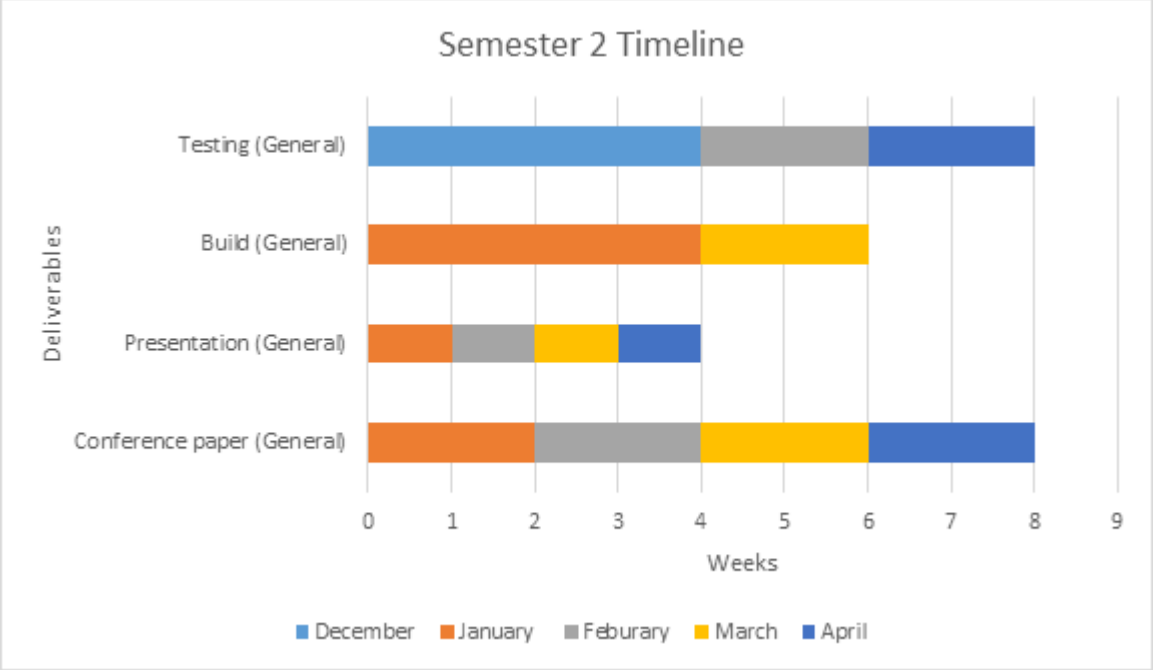


Figure 66: Chart of Timeline in Semester 2 Part A

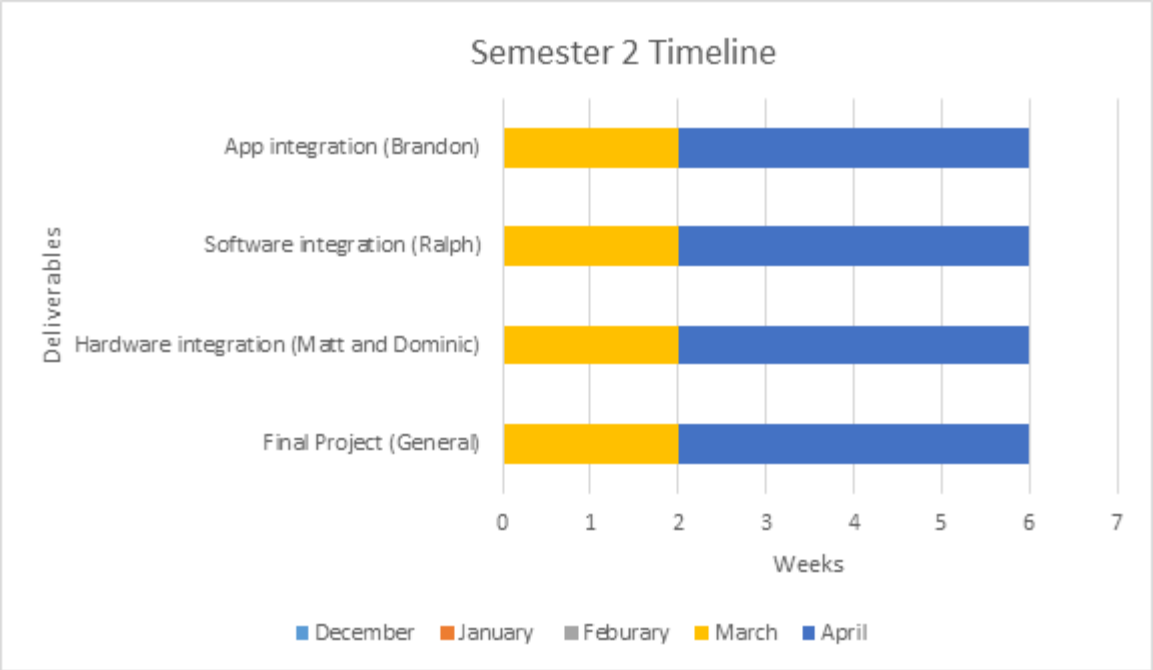


Figure 67: Chart of Timeline in Semester 2 Part B

# 8.2 Finances

| Component | Quantity | Cost |
|---|---|---|
| PCB (Built) | 6 (2 per device system) | $200 |
| Communication Chip | 6 | $10 |
| Microcontroller | 6 | $90 |
| Switch | 6 | $4.50 |
| Power Supply | 6 | $20 |
| Total | | $324.5 |

Table 20: Budget Predictions

Financing of the project is done through the Knight Guard Corporation which is run by Mr. Tom Bland and Mr. Erik Olson. While fully financed, the project was budgeted to still be a low cost product that will can be purchased by anyone. While ordering the PCB, turnkey assembly will be utilized for components that will require a reflow oven to be soldered, which will increase the cost of the product but will guarantee proper placement of components such as the QFN packaged microcontroller chip. Parts for testing were ordered from Adafruit as well as mouser. The cost and quantity of the parts used for testing purposes are listed below.

| **Product** | **Quantity** | **Cost Each** |
|---|---|---|
| Adafruit Micro LiPo Charger | 1 | 6.95 |
| SMT PCB for 48 Pin QFN 3 pack | 1 | 5.95 |
| Slide Switch | 2 | 0.95 |
| 2 Pin Right Angle Connector | 3 | 0.75 |
| 100mAh LiPo Battery | 2 | 5.95 |
| 10 Pack Button Switch | 1 | 2.50 |
| FTDI Friend | 1 | 14.75 |
| nRF52 Dev Kit | 1 | 39.00 |
| nRF51822 Chips | 3 | 4.95 |
| Magnetic Buzzer | 3 | 2.77 |
| | Total Cost: | $84.11* |

Table 21:Test Board Financial Information

*Total cost does not include any taxes or shipping costs

The final product is estimated to cost about $100 dollars per chip. This is given a PCB fabrication cost of around five dollars from multiple venders as well as to cost for Turnkey Assembly, costing over fifty dollars a chip and components to populate the boards.

## 8.3 Conclusion:

The primary goal of the project is to be able to provide a discreet form of self-defense that would be able to be activated from an easy push of a button as well as be affordable to everyone. The project idea came about as the founder of Knight Guard saw his daughter giving others directions and fears what could have happened if they were worse people Targeting everyone from women who fear walking around at night by themselves to police officers who could be given a non-lethal way to defend themselves from others who may be attempting to harm them while in the line of duty.

Challenges that were experienced with the project was to be able to design the circuitry for the activating device and the self-defense device to be small and discreet, while still being easy to be used by anyone in a moment of distress. Decisions made to ensure the challenges were successfully met were to use a microcontroller chip that includes the Bluetooth radio device embedded in, as well as choosing an antenna that was small and could be added to the device rather than expanding the size of the PCBs to have a poured antenna in the device itself. Other decisions made were to have all components as a surface mount package that was 2012 or smaller, keeping the size small enough. Ease of use was accomplished by keeping the activator in a design that would even be able to be activated even if the victim’s arms were completely immobilized and with little effort.

The team divided up the responsibilities for the design by separating into software and hardware groups. Any of the main responsibilities that were to fall behind would be covered by the other member in their mini group as they would have more knowledge of the subject than within the other group. As the first half of the project came the an end, the teams began testing the components and software to ensure each would word individually, and preparations for building a prototype containing all of the components together with software implementation began as it will be built over the period between semesters.

| Hardware Timeline Accomplishments | |
|---|---|
| Week | Accomplishment |
| Aug 22 | Form Initial Group |
| Aug 29 | Discussed Separation of Design and Research Responsibilities |
| Sept 5 | Recruit Final Computer Engineer, Discuss Project Ideas; Meet KnightGuard and Accepted Project |
| Sept 12 | Begin Research: Batteries Switches Microcontrollers |
| Sept 19 | Continue Research: 3-D Printing Materials |
| Sept 26 | Continue Research: PCB Design and PCB Design Software |
| Oct 3 | Continue Research: PCB Finances |
| Oct 10 | Begin Block Diagrams on Device 1 |
| Oct 17 | Design Block Diagrams on Device 2 |
| Oct 24 | Design Schematics on Eagle; Finalize Research |
| Oct 31 | Combine Paper Begin Formatting |
| Nov 7 | Turn in Table Contents; Finalize Block Diagrams and Schematics |
| Nov 14 | Finalize Paper for KnightGuard Review |
| Nov 21 | Break |
| Nov 28 | Final Meeting with KnightGuard |
| Dec 4 | Turn in Paper; Discuss Moving Forward in Senior Design 2 |

Table 22: Hardware Milestone Accomplishments

| Software Timeline Accomplishments | |
|---|---|
| Week | Accomplishment |
| Aug 22 | Form Initial Group |
| Aug 29 | Discussed Separation of Design and Research Responsibilities |
| Sept 5 | Recruit Final Computer Engineer, Discuss Project Ideas; Meet KnightGuard and Accepted Project |
| Sept 12 | Begin Research: MySQL Databases App Design |
| Sept 19 | Continue Research: Communication Protocols |
| Sept 26 | Continue Research: IDE Research |
| Oct 3 | Continue Research:  IDE Decisions |
| Oct 10 | Begin Mock App Design |
| Oct 17 | Continue Mock App Design |
| Oct 24 | Begin Mock Database Design |
| Oct 31 | Combine Paper Begin Formatting |
| Nov 7 | Turn in Table Contents; Finalize Mock App Design for Research, Approval by KnightGuard |
| Nov 14 | Finalize Paper for KnightGuard Review |
| Nov 21 | Break |
| Nov 28 | Final Meeting with KnightGuard |
| Dec 4 | Turn in Paper; Discuss Moving Forward in Senior Design 2 |

Table 23: Software Milestone Accomplishments

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