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Smart Security Dashboard Camera

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1.0 Executive Summary

With the recent automotive break-ins on the UCF campus over the span of one night in spring 2017. The need for the 360 automotive security is evident. This is a very recent noteworthy event, but there are many less known incidents. Prior to this epidemic the focus was around wheel theft which happened at the beginning and ending of every semester. There was no other real way to protect the cars owned by students and faculty other than a beeping horn. The Smart Dashboard camera is more relative today with the growing use of wifi and CDMA technology. With the technology readily available to make this product, the cost to produce this device for most young professionals and working individuals will be affordable. Most college students will be able to afford a variant of the camera. Rearview cameras are mandated in all vehicles manufactured in the US by January 2018. This will bring the cost of cameras and lens way down. Therefore making the cameras cheaper for us to purchase. This will bring down the overall cost of the product to the end consumer.

The project goal is to create a product that can be bought and used as theft deterrent device. This product will be able to detect a disruption due to motion that is unwarranted to the vehicle. Video will start recording when an instance occurs. The video will stop 1-2 mins after the motion stops. Interviews have been conducted at numerous conferences and trade shows. One of the shows was SEMA (Specialty Equipment Manufacturers Association) in Las Vegas, Nevada. SEMA mention, “The Specialty-Equipment Industry Reaches Record $39.18 Billion in Sales for 2016—Up 8% From Previous Year.” [56] A small portion of these sales are in security at roughly $2-$3 Billion. Another show that was attended and customers were interviewed was CES (Consumer Electronic Show). Interviews at both of these shows proved that potential customers and businesses were interested in this type of technology. Data shows the consumer market is ready for the connected car. The future cars will be more connected to the house and the individuals that drive them. Lots of development has been done in this field and will continue to be done.

When interviewing multiple customers and businesses we found out that they wanted security for their vehicles. They wanted GPS tracking, video, and notifications when something happens. Some were skeptical about paying a subscription fee for the service but others had no problem. Although individuals that were previous victims of car or house theft were much more interested. The idea for creating the SSDC is to sell to those who have been victims in the past, and now want security. Also to raise awareness to car security to hopefully get deals with dealerships to make car security mandatory acquiring future profit with companies such as honda.

The device will be light weight, in a discrete location, and have few to no false positives. This means the camera will only record in parking mode when absolutely needed. The Smart Security Dashboard Camera will have hardware and software involved. There will be 1 or 2 main PCB boards. There will be a mobile android phone application to control the camera features, and receive live video feed from remote locations. There will be two software projects on this product, they include the software to run the device, and the software to run the application on the smartphone. The Smart Dashboard Camera will have two 170 degree cameras. The option to add another camera to see out the rear window in full view will be available for an extra cost, but this will not be implemented in the course of the senior design. The Smart camera must work during a hit and run, vehicle theft, smash and grab, wheel theft, and other noticeable vandalism to be considered successful. We would like it to be sensitive to triggers, but not so sensitive that minor disturbances such as cat walking on the car will set it off. The camera will be inside the car protected from the elements. The camera will also send data to the cloud from the camera. That way if the thief takes the camera the video will still be captured. This data transfer can be done over WiFi to save valuable data to the cloud or it can be done via 4G cell phone connection. Where the 4G service will be active in the event of no wifi if the service is activated. If the service is not activated then the vehicle will have to be in wifi range for the data transfer to occur, so if theft occurs in an area outside wifi the only info that can be gained is off the MICROSD card.

This report discusses the design and thought process of the smart dash cam. It first covers what is the inspiration for the dash cam as well as the goals of implementing this project. This paper will then discuss the required design specifications that need to be met for the device to be able to be in vehicles. In the R&D section of this paper it will discuss the comparison between potential parts and modules, and why they were chosen over competitors. After this we will discuss what constraints that were experienced in the designing as well as the implementation. Some of these constraints are things such as including things such as bulkiness incorporating a separate battery to power the dashcam during idle durations. Other constraints involve industry standards that have to be met in order for the device to both be able to survive in a harsh car environment as well as be allowed to be sold at market. The following section will involve the hardware and software of the device this includes the block diagrams, flow chart, and applicable schematic designs. The hardware design of the device will include the dashcam pcbs as well as the interconnection power design. The software will discuss the application for operating the dashcam, code to run the pcbs, and why we chose both wifi and 4G. Next the paper will explain the reasoning behind the aesthetic design of the dashcam, and why this design is optimal for a car security dash cam. Afterwards, this paper will give a thorough explanation of how the device was tested in order to ascertain if it met a desired level of competence. The paper will go over what overall budget for the project was as well as the development cycle that was undertaken to achieve the creation of the device. Then the paper will review the administration of work for the project. This will cover each member's personal responsibility in the Project as well as the areas that they will be assisting with. Some areas are slight grey areas that all of the group will be expected to assist with if the area is not well known to anyone in the group.

2.0 Project Description

This chapter outlines the Smart Security Dashboard Camera (SSDC) project as determined by the group. The chapter illustrates in simple terminology and through the utilization of pictorial documents the design of both the hardware and application aspects of the project; block diagrams are provided to illustrate both the hardware and software components as well as the interaction between all of the components. As well as providing documents in relation to the overall project's goals and achievements, especially those that may be prudent to showcasing the product at a high level. The goal of the chapter is to provide insight on both the product and intended design criteria to be identified and prioritized in later sections. The below table illustrates at a high level components utilized in the project as well as the goal and minor specifications of each component in the overall design.

2.1 Project Motivation

On UCF Campus alone there have been 30 plus vehicles that have had their windows smashed, items stolen, and privacy disrupted according to ucf police reports. There have been suspected hundreds of unreported other accidents that have affected the lives of many students. The reason that many of these accidents and thefts are either not reported or do not get solved due to an obvious lack of evidence. According to the Department of Motor vehicles there were 721,053 successful attacks on cars in the US in 2012 alone. Of these thefts and attacks on vehicles a majority of them were on unattended vehicles making the identification of the thief as well as arresting of them very difficult. The Dash cam will not only identify that a vehicle is in distress, but functions as a form of tracking your vehicle and giving video feed of who the assailant is. This will drastically increase the probability of arresting the potential thief, and gaining compensation for damages. If this project can reduce the estimated, “4.3 billion dollars” of lost money due to car related damages and thefts; the project will be considered successful in terms of our original desire.

2.2 Goals

- The dash camera will have a clamping function to allow for easy portability between vehicles, and give some level of discreteness

- The dash camera will contain a low power picture mode to allow for lower energy costs to the power system during inactive times.

- The dash camera must be calibrated to be able to tell the difference between a true crisis compared to a truck passing by. This is due to the need to reduce unnecessary alerts, and to inform the user of when the vehicle is under real distress.

- The dash camera will need to be able to have an almost 360 degree view to give a clear line of sight to most possible points of impact/concern. This will be addressed by implementing two cameras with wide angle lenses for 180° viewing.

- The device must not be bulky so to not distract a user during driving, and not impede crucial lines of sight. This will be achieved by using a locking mechanism to secure the camera to the rear view mirror minimizing the obstruction of view.

- A few possible objectives are to implement are thermal heat conversion pads to convert thermal energy to electricity, including a portable seperate battery, and a system for facial recognition is being considered.

2.3 Function

The purpose of this project is to provide detection and accountability 24/7 for a vehicle. During a vehicular accident the chances of getting compensated for an accident where you are not present in the vehicle are all dependent on whether the individual who injured the vehicle left a note or not. Without any evidence other than paint left from a dent or a streak mark on a vehicle there is very little that can be done to achieve due process for the one responsible. The desired function of the dash cam stated before is to give digital evidence of what has occurred during an accident to an unattended vehicle. However, this does not stop at just stationary parking surveillance, but this device will also allow for constant surveillance during driving. According to esurance during a car accident you should follow a few basic steps which summed up are if able to move your vehicle to a safe area, check on those affected, and then gather information as well as call the police. These steps are the typical steps many insurance companies tell their customers, but another key step that cannot be overlooked is that they also suggest customers do not admit their faults. Many people unknowingly follow this step even if they have never been told to do so. In the court of law according to john helms a dallas criminal defense lawyer a case where both sides claims no fault turns into a he said she said style of case. This means that the only thing that a judge or jury could use to determine the case is any recovered evidence which can be scarce, and the involved parties testimonies which under oath are considered evidence. The dash cam's function removes the possibility of he said she said by giving a direct view of what happened at the scene of the crime.

Other than security and documentation of surroundings a vehicle the dash cam also offers a secondary function of ease of mind. There are two forms of stress eustress and distress. Eustress is health and allows for though contemplation of issues. Distress is unhealthy and caused by issues of life that are typically unplanned. The dash cam removes the distress of both worrying about your vehicle while unattended, but also allows you to know that you will have documentation should any problems arise on the road.

2.4 Related Works

Currently there many other market dashcams, but the one that is the most similar the Smart Security Dashboard Camera (SSDC) is the Waylens 360 security camera. The difference between the products is easily described with their designs. The SSDC is designed to be more discreet, compared to the Waylens flying saucer design. The SSDC also uses two cameras compared to the Waylens one HD 360 degree camera design. Also it is desired that by the time the dash camera goes to market it will contain 5G compared to the current generation 4G camera designs. This will be a key differentiator for the product compared to the others on the market. The Waylens security camera has the ability to support up to 256GB of memory to the microSD card. They will also send this data to the cloud as a service for customers so that in the instance that something happens to their camera or memory card the footage is still safe.

The Blackvue dash camera records in 60 fps and has Full HD 1080p, and the camera is a top contender in the price level of the SSDC. The Blackvue company offers the option of two cameras or one camera. They sell this set up as one channel or two channels. They also offer up support up to 128 GB microSD memory card. The Sony Starvis camera sensors offer supreme night recording and and day recording. The Dash camera offers one 139 degree camera. Another 139 degree camera is available for the rear windshield at an additional cost. The dash camera also comes with an infrared light used in conjunction with Sony Starvis sensors that help to capture video in all light settings. This is especially useful at night or dark parking garages. The camera includes GPS so that speed and location can be recorded as well. This is useful to post speed on the video output. It is also useful if the user forgets where they parked their car.

The Thinkware Dash Camera has the ability to record in Full 1080p HD 140 degree video at 30fps. The camera quality is 2.19MP Sony Exmor CMOS technology. This camera also has parking mode, lane departure detection and red light camera alert. Thinkware also has the option of 2 channels. This includes 2 cameras with the Full 1080p HD 140 degree video technology. They are not as well known as Blackvue in the United States. They are known in Canada better than the US. Thinkware is a direct competitor to Blackvue and the SSDC. They have a two channel output as an option for customers. The SSDC will have two channels as a standard for customers. This will put it one step above the traditional Dash camera companies. Thinkware has the parking mode continuous recording option just like BlackVue.

Some more highly regarded dash cameras are the Cobra CDR 900 for $299.99 or the Garmin Dash Cam 65W for $249.00. The Cobra CDR 900 uses a 1080P HD video camera and an Ambarella™ A7LA chipset to ensure high-quality imaging, even during nighttime. The Cobra Dash Cam has a frame rate of 30 fps. It is Wifi enabled and has a 160 degree viewing angle. The Garmin Dash Cam 65W is a 1080p with 180-degree field of view. It has a framerate of 30 fps. These two cameras a very comparable but they are lacking the ability to send video in a live stream. The user has to wait until they get back to the vehicle.

2.5 Requirements Specifications

The requirements for the Smart Security Dash Camera (SSDC) are components that will detect cases for car theft and car damage, a mobile application to notify the user of the scenario when the device triggers, a GPS tracker to detect the car's position for the user, and a source to charge the device. Multiple components, such as an accelerometer, a gyrometer, and a magnetometer, will be used to detect the car thefts and car damages while also be coded to filter any false positives. The mobile application will be used on an Android device and a GPS chip will be used to track the car's position from the user's device to the user's Android application. The device will be powered by a hardwired that will be connected to the car.

- **Accelerometer**
    - Must be built in to measure and detect acceleration forces when the vehicle is stationary
    - Must be able to detect any unusual acceleration forces or vibrations when the user is inactive of his/her vehicle which will send a signal for the camera to record the instance
- **Gyrometer**
    - Must be built in to measure and detect angular momentum when the vehicle is stationary
    - Must be able to detect any unusual angular momentum when the user is inactive of his/her vehicle which will send a signal for the camera to record the instance
- **Magnetometer**
    - Must be built in to measure the direction of the vehicle when it is stationary
    - Must be able to detect the change in direction of the user's vehicle from the measurement of magnetic fields and will send a signal for the camera to record the instance
- **Cameras**

- Must be high resolution cameras with at most 170 degree FOV
- Must be able to record consistent footage whenever the camera is active
- Must be a 16 megapixel digital camera
- Must have a battery saver mode to use less voltage from the user's vehicle when it is inactive
- Must be able to save recording footage if the camera gets damaged
- The camera must be connected to the rear view mirror of the user's vehicle
  - One camera must face the inside of the vehicle as well as being positioned to view the side windows and back window to have a view of any car theft and car damage that occurs on the sides of the car
  - Another camera must face the front window of the vehicle to view the car theft and car damage in front of the car and record footage of user's vehicle when it is driven on the road
  - The camera must be positioned and mounted on the rear view mirror in a way that it has view and able to record footage of the car theft and car damage taking place and be kept stable during driving or scenarios of vibrations or extreme forces

- **Android Application**
  - Sends a notification to the user, even when the smartphone is silent, if the recording camera detects any car theft or damage
  - Must be easy to use and understand for the user
  - Must use Bluetooth, Cellular, or Wi-Fi to interact with the recording camera and for the user to see the recording footage
  - Must be able to store recording footage to the application
  - The recording footage and user's data must be protected and encrypted
- **GPS Tracker**
  - Must be built in to detect if the user's vehicle is moving out of place when the vehicle is inactive, either from car theft, or the vehicle is being towed

  - Can be used to help the user find their vehicle when they don't remember where it is

- **Hardwire Charger**
  - Must be built to charge the recording camera through the vehicle's battery

2.6 House of Quality

The house of quality shown below gives a visual representation of the marketing requirements compared to the actual engineering requirements for the dash cam to be successful.

The engineering requirements are the things that need to be focused on in order for the device to function at peak functionality. An example of this is Mega Pixels need to be at a certain levels for the dash cam to be recording at 1080p hd compared to a low resolution 480p. The engineering requirements are typically separate from cost consideration, and the reason for the house of quality to exist is to make a general comparison between the engineering requirements compared to the marketing requirements. In the dash cam the install ease is lower due to the expectation to make the dash cam need professional installation, and this is due to the engineering design requiring the power to come from the car battery instead of a portable battery.

The marketing requirements are essentially the design variables that make the dash cam desirable to the potential consumer, and the purpose of identifying these elements is to balance them with the engineering requirements. The consumer of this product ideally would want the device to be low cost, have a high resolution, and be very easy to install. The problem with this is that many of these things would require higher prices due to the increases in the engineering requirements. An example of this is to make the resolution 4K, however this increases the needed memory for data storage, a more powerful camera that would require a larger power supply, and would require a completely different PCB design. Another major market requirement that needs to be thoroughly addressed is the reliability because if the device does not function as expected then the product will become undesirable. Also the dash cam needs to not be activated while the car is sitting idle unless there is a true accident as a result the reliability of the device needs to calibrated to be high, and as a result the failure rate has to be properly addressing creating a larger engineering requirement. Focusing to much on any one section can result in time wasted, and a loss of profit. Ideally the engineering requirements need to be balanced with the market requirements enough so that the product is quality and cost efficient trying.

Legend:

↑↑ - High
↑ - Medium
~ - Low

		Failure Rate	Megapixels	Bandwidth	Foot Print	Cost	Idle Run Time	False Positive
		-	+	+	-	-	+	-
1) Camera turns on when car moves	+	↑				↑	↑	~
2) Video sends to phone over Wi-Fi via app	+	~	↑	↑↑	↑	↑	~	
3) Video sends to phone over 4G via app	+	~	↑	↑↑	↑	↑	~	
4) GPS location sent to phone via app	+	~		↑	↑	↑	~	
5) Cost	-		↑	↑	~		↑	↑
Targets for Engineering Requirement		<5%	> 6 MP	>4G	<6 Inch Diameter	<$350	>1 Weeks	<5%

Figure 1: House of Quality

<u>Failure rate:</u> hardware failures such as shutdown, battery failure
<u>False positive:</u> percentage of false positive and negatives.

↑ = positive correlation
↑↑ = strong positive correlation
↓ = negative correlation
↓↓ = strong negative correlation
\+ = positive polarity
\- = negative polarity

2.7 Hardware Diagram

Hardware diagram illustrating the numerous components of the physical device as well as potential add ons that may be added to the final product in numerous versions when going to market, such as a bluetooth module over wireless for enhanced power saving. The diagram also illustrates the communication routes between each of the components, and arrow indicating the flow of traffic to a device as a receiver.

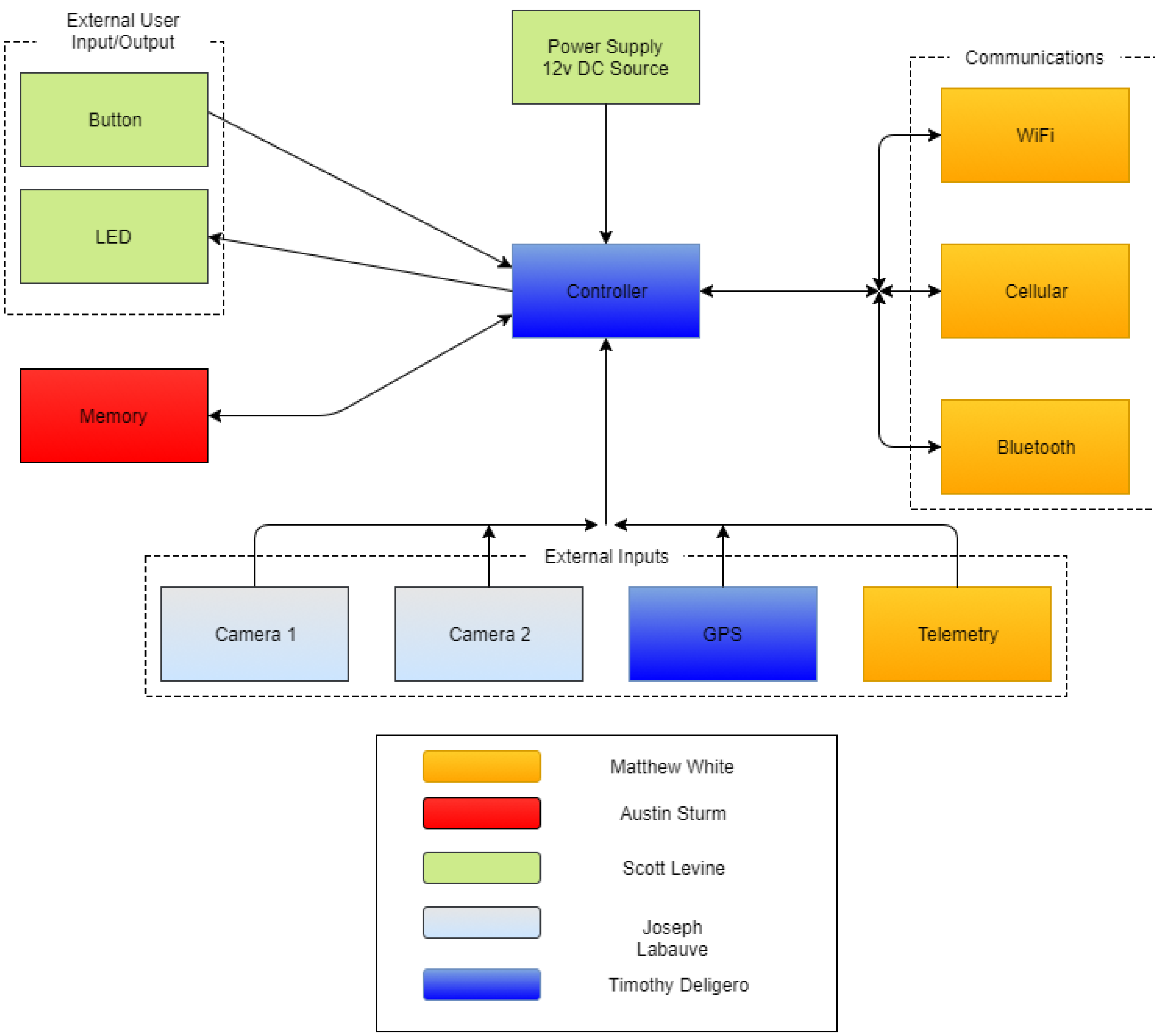


Figure 2: Hardware roles given to team members

2.8 Software Diagram

The software diagram provides insight into the applications features as well as tracks the basic flow of communication between the two mobile application and the physical device. Lower level flow charts for application design and information tracking will be provided later as well as any necessary external documentation. The diagram below shows that board software will control the different components of the Future PCB. The analog features on the the board will be the push button and the LED light, and the rest of the components will be digitally controlled. The app will communicate with board through the use of the cloud, and will provide basic features once the connection is established.

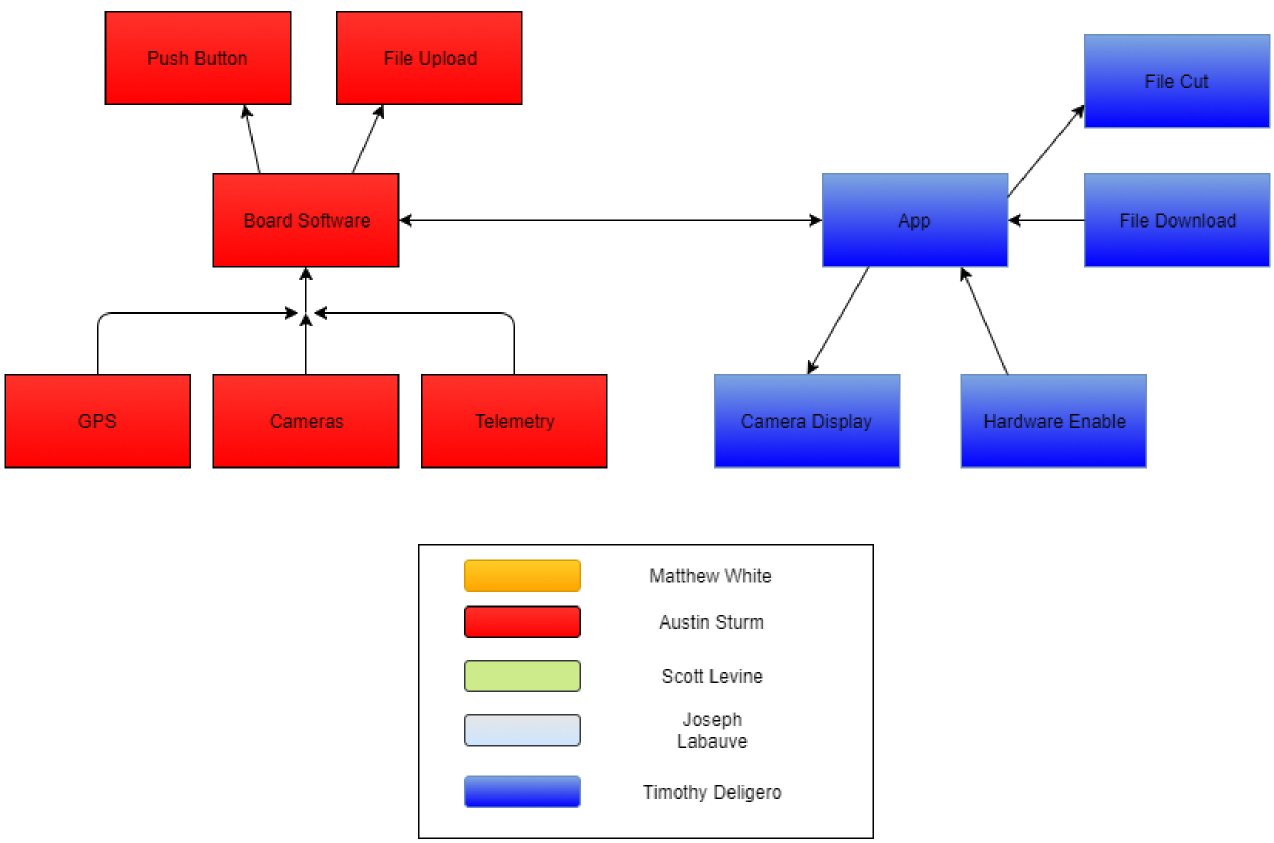


Figure 3: Software roles given to team members

2.9 Brief Operation Manual

The SSDC is a stationary security camera for vehicles to protect and secure vehicles from aggression. The SSDC has a simplistic setup listed below, but connecting the device to the car battery does require professional assistance or automotive knowledge. This decision was made to protect the user from either electrocuting themselves, or compromising the protective firewall while trying to install the device. Once the device is connected to the battery the SSDC is simply attached to the back of the rear view mirror through the use of a rubber tipped clamp. The choice to put the device on the back of the mirror is an aesthetic, legal, and discretion choice. The aesthetic reason for this is to not add to much to what drivers already see when driving allowing for a feeling of security with large changes. Along with trying to not obstruct the view of driver this is a legal matter due to some states and countries not allowing large obstructions located on the front windshield. This location also happens to be the easiest choice for discretion allowing the device to function as intended without drawing attention to itself from passerbys. Once the device is secure it must be turned on as it has to be connected to your phone.

Once the device is securely latched down the next part of the setup is to setup the Mobile application. To do this the application will first be downloaded then an account must be setup to link the camera data to the account. Once this is setup the connection between the device and the application will be established allowing for data to be transferred when in wifi range or through the use of cellular data transmission. The settings for the device can be setup through the application though these will be limited for senior design.

Steps to setup the SSDC

1) Have the device wiring physically installed by a mechanic or professional installer capable of wiring the device through the firewall of the vehicle and into the fuse box.

2) Clamp the SSDC to the back of the rearview mirror where it sees both the front windshield and back window.

3) Setup the mobile application following the instruction provided with device, and sync the device with the mobile application.

3.0 Design Constraints and Standards

The following chapter outlines design parameters and specifications related to the project. These requirements are designed based on the project objectives, industry standards such as a temperature range of -40°C to 85°C, a humidity range from 0% to 100%, and a target field failure rate of less than 1% [57], as well as following security best practices. The device is intended to be a secure product line, keeping the consumer in mind by ensuring new attack surfaces are not introduced by the product.

3.1 Device Dimensions

Device dimensions severely impact the marketability of the product; users typically would not purchase a product which takes large areas of window space. This is not only a marketing concern but as well as a safety concern; a product which envelops a large amount of windows space may disrupt the driver's vision leading to potential accidents. The design choice of putting the SSDC behind the rear view window is also a legal protection choice due to some states in the US as well as other countries prohibiting a certain amount of the windshield from being blocked. Securing the SSDC to the back of the window will results in a less distracting front view while being more aesthetically pleasing. The device will be designed to fit neatly behind the drivers rearview mirror to maximize driver visibility, while still maintain full camera view of both the interior and exterior of the vehicle. Max dimensions would be below 20.32cm x 7.62cm x 5.08cm (LxWxH) app as this is the typical size of rear viewing mirrors. Also if the choice is made to install an extra camera in the back of the vehicle when the SSDC is brought to market the camera will discreetly fit in the top middle of the rear windshield. It is believed that this location with optimally not cause distraction or be easily noticed. The dimensions of the rear camera would be minor as the device would be connected through a long ribbon cable going through the ceiling of the car. This additional camera would have to be professionally installed to reduce damage to the vehicle.

Summary:

- The device fits behind rear view mirror
- The camera's are back to back and capture near a 360 degree video
- No larger than 20.32cm x 7.62cm x 5.08cm (LxWxH)

3.2 Cameras

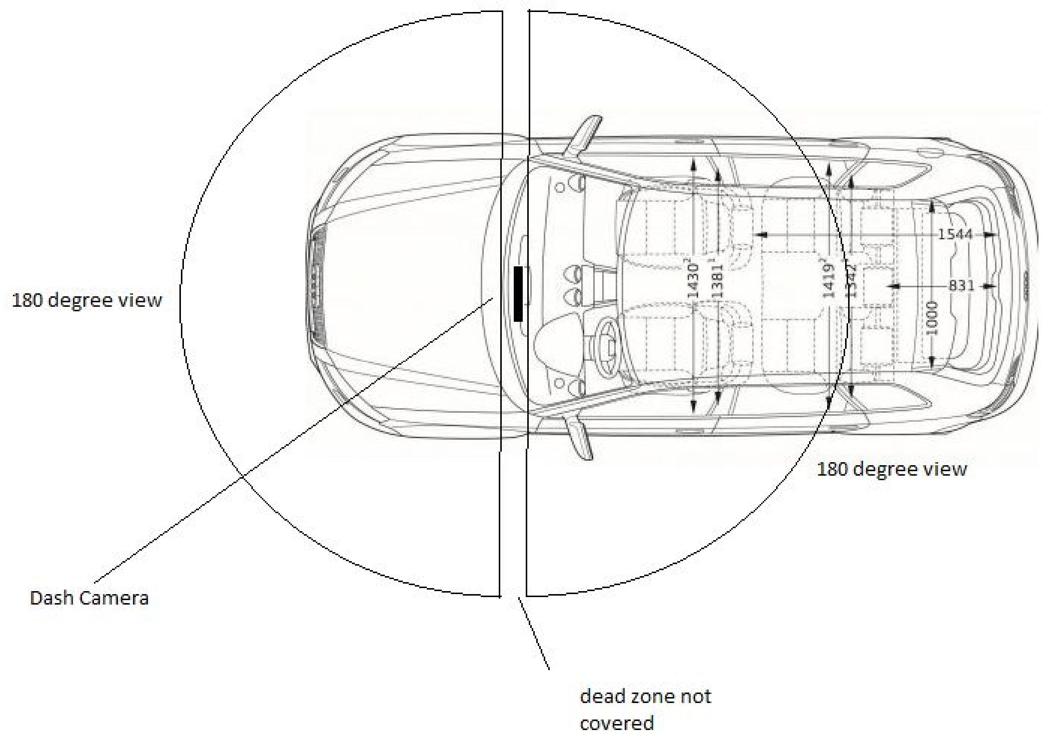


Figure 4: Camera view radius

The essential features to this product is to provide valuable video evidence during critical moments. This requires two cameras to provide full comprehensive evidence of occurring incidents; they need to provide clear view of both the interior and exterior of the vehicle. Optional attachments may be provided to ensure that the product has maximum visibility, ensuring any incidents may be accurately recorded. This will require two cameras of approximately 170 degree view, one facing out the the front window and the second facing towards the interior of the vehicle. Both cameras of a high enough resolution to provide clear imagery of any potential incidents.

Summary:

- Two cameras will be placed on the dash camera unit
- One camera facing towards front window
- One camera facing interior
- Dash cam while driving
- Security camera while parked
- 1080p resolution camera

3.3 Telemetry

Telemetry is responsible for the most crucial aspect of the product, incident detection, the sensors are responsible for determining if an incident occurs. The mixture of sensors will be programmatically designed to detect jumps in telemetric data; the design minimizes false incident rate and efficiently detects when incidents are truly occurring. Accelerometers utilized to determine if the vehicle experiences a strong force, it must be able to detect spikes of motion. Gyrometer to detect if the vehicle has been flipped or is in the process of being lifted, this can be utilized to detect towing. GPS tracking enabled to determine vehicle longitude and latitude for the vehicle position monitoring in the event of theft.

Summary:

- Accelerometer which will identify if the vehicle has moved in any direction, and the magnitude of the change in movement.
- Gyrometer to detect changes in pitch, yaw, and roll.
- Magnetometer to determine direction
- Global positioning system (GPS)

3.4 Storage

All monitored statistics and recordings will be stored for up to approximately 256 GB's of data. The storage device will be a micro-sd that may be replaced by the user to allow for easy storage. Upon reaching 75% of the theoretical limit the device will begin to rewrite over old files to ensure all recordings are saved. The data will be offloaded automatically when connected to to a known wireless network, upon complete upload the data will be wiped. The remainder of the 25% storage space is preserved for any crucial recording when the car is parked or moving, and any action activates the accelerometer, gyrometer, or any other component. When and if the device is connected to the cloud via CDMA technology the dat will flow directly to the cloud and minimal space will be used on the microSD card.

Summary:

- Micro-SD support up to 512gb SDXC
- 256 GB card provided
- 75% data limit

3.5 Communication

A security product would provide little benefit to the user without the ability to offload evidence to a remote device; Utilizing local storage the device could be destroyed by the offender, rendering the device's objective failed. The device will implement a remote communication method to allow for the transfer of sensitive files. In order to provide this functionality implementation of both WiFi for local transfers near known networks, as well as cellular for areas without known wireless networks. Both chips will exist on the same board, and the cellular chip will activatable at a later date if desired through a monthly rate that will be decided upon after senior design.

Summary

- Code Division Multiple Access (CDMA), or Global Systems for Mobiles (GSM) communication devices to allow 4G mobile internet access to communicate with the user's mobile phone and upload video to an online database cloud service.
- Wi-Fi connection access device to allow non-mobile internet connection to upload videos from home, office, or hotspot location.

3.6 Safety Devices

Certain safety functions will be included with the SSDC. The SSDC will be attached to the rear view mirror which is the ideal position to include safety devices within it. Considering the possibility of people sleeping in a running vehicle the device will reduce the chances of certain unintentional injuries due to dangerous gases, or loss of person's with the vehicle in the case of children or the elderly. This will be achieved through the use of gas monitoring sensors to alert of excessive harmful vapors through noises, and phones alerts. Also this will be done through the use of gps tracking to keep track of vehicle location.

Summary:

- Carbon Monoxide detector to ensure any occupant in the vehicle is not inhaling an unsafe level of carbon monoxide. The detector will create a push notification to the user's phone as well as an audible sound to warn occupants of the vehicles who might not have access to the user's phone.

- GPS tracking for children or elderly parents. The GPS coordinates will be displayed on a mobile map within the application so the users are able to see the location interactively. The GPS tracking can be used to find elderly family members that are lost or disoriented. Also, it can be used to monitor young drivers as they first start out. The technology will also be used to track the car's location in the event it is stolen or if the user has forgot where they parked. This will insure the location is known at all times. Increasing the overall safety for families.

- With the added benefits of these safety features other technologies can also be combined to help make sure the driver and other drivers around are safe at all times. This could be as simple as checking in with a new driver or keeping up with current traffic to help redirect your spouse on their way home. There uses that may have not been discovered yet but the hardware and software up dates to make the technology more viable will be there for the future.

3.7 General Data Protection Regulation (GDPR)

An important piece of legislation was passed in the EU on April 14, 2016 that will affect any business that has any form of control over an EU citizen’s data. This legislation is called the EU General Data Protection Regulation or GDPR, and its function is to protect the information of EU citizens. This legislation simplified requires that the same level of security be given to people's general information as is given to say Social Security number or bank passwords. A key change compared to prior information protection laws set by the EU is that any information processing company found to be not properly securing people’s information will be fined regardless of where a breach occurs at. This point is key due to the complex way people’s data can be stored anywhere in the world, but can be accessed in the EU almost instantly. This However means that if an american company that does small amounts of business in the EU and gets breached the EU will now have the authority to fine them up to 4% of annual global turnover or 20 million euro whichever is higher. This legislation becomes active May 25, 2018 [58]. Another key component of this legislation is that should an EU citizen request to know if their data is being processed they must be informed if it is, and if that data is requested an electronic version of it must be provided free of charge. Also this data must be erased if it is requested to be by the citizen.

For the SSDC this means that performing business comes with an additional risk should there be a breach in EU citizen’s information of any kind. Business with European countries will come at the cost and risk of increasing the security measures of the SSDC, so that cyber threats to the system. This is primarily done through by encrypting the data to stop the ability to decipher the information. Also the ability to track specific users data must be possible so that the data can be removed if requested to do so, and the need to more thoroughly monitor the data of people can raise further issues regarding privacy. This means that a support service has to be created if it is desired to do business in the EU resulting in a higher cost and the need for more resources.

3.8 Timing and Economic constraints

Economic constraints are constraints due to monetary or financial means. This project has a high economic constraints due to this entire project being funded by Matthew white. The costs are discussed later near the end of this this paper lists the necessary components as well as their necessary costs per part. This does not factor in labor costs due to this being a project for senior design. However, due to the project being funded by a current student the economic constraints must be adress, and this project is projected to go to market increasing the initial economic constraints much broader amounts in the future due to mass production.

The timing and economic burden of the SSDC are limiting constraints. This device has to be fully designed and implemented during the next 5 months. This produces tight time constraints for the project to be completed. Monetarily the device can be created as a prototype but at a high volume. In a high volume arena the capital needed to make 2,000 - 3,000 units would need to exceed $350,000. The $350,000 will provide enough capital to make the first initial batch of PCB's and the plastic injection mold for the outer shell. For senior design class the cost of this unit prototype should not exceed $2,000. This will include the plastic shell, electrical components, printed circuit board and two cameras. For senior design the team looks to create an MVP but also an off-tool product that looks similar to a plastic injection molded part. The MVP will come first and be rather larger and bulky but the smaller finished product will be the off tool part. This outer shell of the SSDC will be smooth, sleek, and close to production ready. The goal within our given constraints will be to produce a close to production ready model. This will take lots of time and resources. The Kickstarter will also be launched right after senior design. This will insure the funds could be raised before talking to investors.

Due to the monetary constraints of having a student sponsor the research and design of the project have to be carefully designed and purchased. This means that multiple possible components cannot be purchased for testing. This is due to the high cost of either creating a PCB with the new components or even testing the components on a breadboard with development boards. Development boards for many of the components being considered for the PCB such as wifi, CDMA, and camera sensor modules cost in the range of 100 to 1000 dollars. If any of the components selected are found to not be compatible with other components they will be changed in the selection part of this paper, and if any components are found to be needed they will be added to the cost analysis/budget section of the paper.

Timing constraints for this project are constraints caused by required project achievement dates and goals. This means that certain parts of this project need to be completed by certain dates. This is an important consideration especially during the research phase of the project, and the testing phase of the project. Certain amounts of this senior design paper have to be completed these are listed in the Time table near the end of the paper, and these essentially rush the project which cause the researching of parts and contacting of companies need to be done in a short amount of time. This dialogue with companies to get testing parts can take an extended amount of time, and certain parts will not be able to be acquired in the time tables listed even if this dialogue is started at the start of senior design 1. Also a the time tables for senior design 2 are not yet known, but it is known that most of the software design will be done during this semester. This software for the SSDC needs a thorough amount of time to properly code the base functions of the device. The senior design 2 semester is only 16 weeks, so this is the maximum amount of time for coding and testing of the SSDC. The base code for functionality requires a lot of time, but afterwards it will require fine tuning to stop false positives from arising. This fine tuning will require a lot of extra time in testing the product in multiple environments requiring extended periods of testing that need to be done. There is also the timing constraints of organizing meeting times between the five group members in the group.

3.9 Legal constraints

With the use of the SSDC there are specific laws that must be abided by when considering if it is okay to record another party in a state. To help understand the law two terms must be properly defined which are single party and all parties. Single party refers to one person who is part of a conversation or discussion, and all party refers to everyone that is part of a conversation or discussion. Many states allow for the recording of individuals and conversations only requiring only that the single party recording be part of that conversation or dialogue in some form or fashion. However, there are select states that require all parties to agree consent for the recording process before recording can happen. Often these laws refer to audio recording not video recording, but there are also grey areas in these laws such as if the incident in question is a private discussion or under the expectation of being public. Some states in the US that do not allow for recording without consent of all party members are Washington, Illinois, and Pennsylvania. Now these recording laws have exceptions and stipulations that can allow for recording, but to simplify the legal process a section will be created in the User agreement documentation that will require the user to look up recording laws in their particular state before using the device.

In many European countries there are legal grey areas revolving around dashcams due to European data protection laws. In some countries such as austria there are fines given if a dashcam is found in the vehicle. In recent years many laws are changing or being updated. The recent GDPR discussed earlier will impact a lot of data and surveillance devices in the current years. Currently this will highly affect CCTVs, but dashcams are not considered CCTVs. However, this puts dashcams in a grey area that will likely be defined through precedent court cases, and further legislation as well as amendments to laws. However, in some countries dash cams are altogether forbidden from being used such as switzerland.

While the dimensions of the SSDC were stated before there are certain legal restrictions regarding the mounting of devices on windshields for both size and location. Many states allow dash cams, but do not permit them to be mounted to the windshield. Also the area which the device is allowed to obstructed changes widely from state to state. These constraints have affected the design, and mounting choice greatly during the design phase of the device. As a result of the existing laws the choice was made to attach the camera to the back of the rear view mirror as to circumvent the issue of window mounting laws and reduce area of obstruction.

3.10 Environmental constraints

The environmental constraints to overcome in this project are the harmful effects that the environment of being mounted in a car creates for the SSDC. These are very important to address during the design phase of the SSDC since this project is projected to go to market eventually. These environmental constraints are mainly concerns with regards to trauma due to acceleration changes as well as thermal changes. These factors can be overcome through proper component selection by analyzing the datasheet to determine compatibility with the environmental standards.

3.11 Social constraints

When designing the SSDC both functionality as well as human psychology were taken into consideration, and measures were taken to try to provide a level of appropriate social acceptability for consumers. It is not uncommon for people to become agitated or angered when they find out they are being recorded without knowing beforehand. These situations can cause tension, and uneasiness in pedestrians as well as other drivers. To try to circumvent anger as a result of being record the SSDC was designed to be discrete as mentioned in the Design dimensions. This removes a significant amount of attention from being drawn to the SSDC, and as mentioned in a later section the SSDC will have customizable colors in the future allowing for the camera to match most mirror colors to blend in even more. However, this will play a lower factor when it comes to the functionality of the system.

3.12 Ethical

The ethical constraints of this project fall within the material choices of the project to guarantee an easily disposable and/or recyclable product, and to meet the specification standards we set for ourselves. To do this the materials chosen for the SSDC will be environmentally friendly meaning they can be salvaged or recycled. Since this project is a designed to be a sudo security system. Considering that this system needs to be very accurate. We have an ethical responsibility to not choose shoddy components that will not function optimally. Thus we will not cut corners on components for the SSDC based on price to turn a larger profit. Also there is the ethical concerns regarding public filming of individuals. However, the first amendment protects public speech which involves recording individuals as long as the recording is done in a public space, and is done without the intent to gain private information.

3.13 Quality and safety

The quality and safety constraints for this project are the constraints concerning the health and safety of the consumer. To achieve these goals the SSDC will not be produced using toxic materials dangerous the health of those that interact with the device, and the device will be given proper time and consideration for it’s design before it is brought to market. All parts that will go into the PCB will be tested to show that proper function is achieved. The design of the PCB for the SSDC will be created using optimal setup by separating the analog and digital components, using minimal tracing width, and not use dysfunctional or untested components. Through carefully component selection and testing of the device the possibility of the device malfunctioning or even worse causing damage to the vehicle or surrounding area cause can be avoided. This device needs to go directly to the car battery, so it will have to go through the firewall of the car to reach it. To protect people from either electrocution or damaging the very important firewall of the vehicle the device will very clearly declare in the instructions and on the packaging the need for professional installation. Finally the product will not contain toxic materials, and will be light enough that in the event of the product becoming dislodged due to extreme trauma it will not cause major injury.

3.14 Power supply constraints

In the SSDC there are multiple issues surrounding the the power supply going to the SSDC. The SSDC does not have any relevant power constraints while the vehicle is on due to the constant flow of power, but once the power is switched off the device has to continue to function in low power settings. This means if the SSDC is connected directly to the battery of the vehicle the battery will slowly be drained, and while this will not pose a threat should the vehicle be driven occasionally extended absence of not driving can cause the battery to reach critically low levels. To remedy this it is believed that low power settings as well as a cutoff point should be created to preserve the vehicle battery.

The SSDC while on is a dashcam, but during vehicle shut down it acts as a security system that needs to be able to react fast. An issue with using the car battery for this power supply is that should the car battery run to low and the shutoff is activated the device will not function as desired, so an option that is being considered is the installation of an exterior battery that is used to keep the device primed for should any issues arise.

3.15 PCB Design Constraints

3.15.1 Thermal control

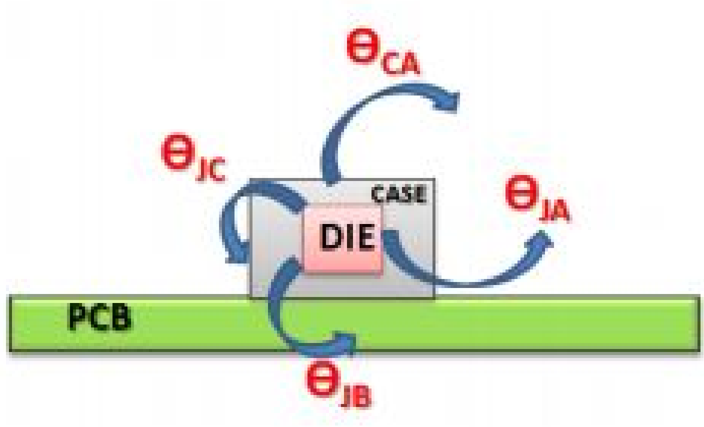


Figure 5: Thermal heat dissipation (Permission Pending)

Control of thermal elements is an important process in modern circuitry due to the desire to make PCBs as small as possible, and the effects that overheating can cause. This is even more crucial in the SSDC since it will be located in a highly variable environment. According to a study performed by Jan Null recorded car temperatures can reach temperatures of 132 when ambient temperatures outdoors were only 82 degrees fahrenheit. It also has to address how fast temperatures can fall resulting in a dangerous thermal shock for sensitive electronics not prepared for drastic changes. This shock however can be reduced in a variety of ways by the use of external heatsinks like those found in computers, but for small devices like the SSDC a method of thermal dissipation is using copper tracing due to it having a better power efficiency value than other materials used for tracings combined with minimal heatsinks.

Power dissipation is typically given in the form of $\boldsymbol{\theta}$ and having the units Celsius/Watt. 10C/W power dissipation would mean that there was 10C created for the dissipation of 1 watt. The temperature itself for each component is broken down between the the case and the junction, case and ambient, and junction and ambient from notes of Arthur weeks. [66] Each of these can be calculated to find the heat created by each component. The total temperature differential is calculated by the equation $T = \#watt * \boldsymbol{\theta}$ canceling out the watts in the units and leaving the temperature in C[66]. For the device the to be considered reliable the total heat created by the component would have to be less than Tjmax or the max allowable junction temperature.

3.15.2 Tracing Inductance and Board Layout

The layout of the PCB for the SSDC is very important due to the use of copper tacing mixed with the CDMA and GSM high frequencies. Typically the impedance of the copper is negligible, but these high frequencies can affect the copper enough to cause high impedances. The impedance of a copper tracing is given in the first calculating the inductance of a tracing using the equation below. Then calculate the resistance of the component using the inductance and frequency.

$$Inductance = .0002 * L(ln((2 * L)/(w + h) + .2235 * ((w + h)/L)))$$

Lower frequencies cause the impedance caused by this inductance to be so low that the value is negligible, but when the values of frequency reach into the gigahertz or high MegaHertz this value becomes large enough to cause issues. There is a technique to lower this however by placing the output and return paths close to each other.

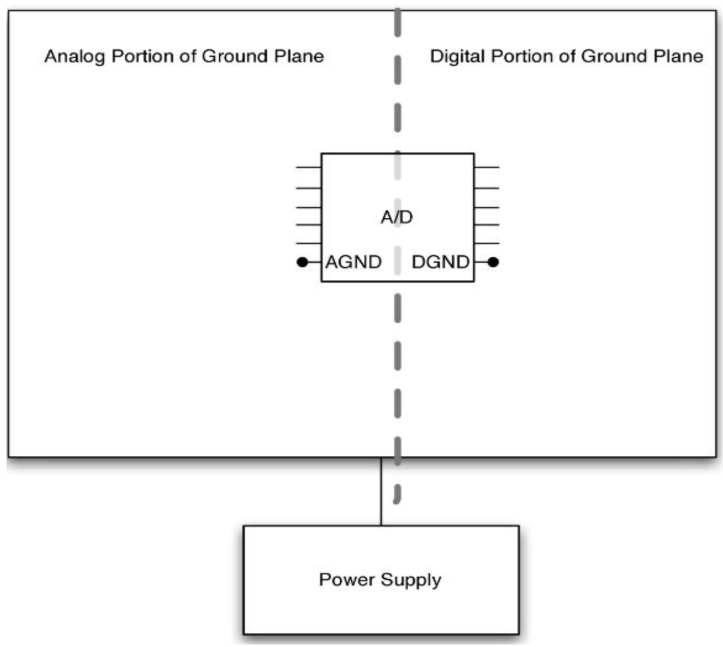


Figure 6: Partitioning of analog and digital [Permission Pending]

Placement of components on the board is a crucial part of good PCB design. Correct setup of a PCB should put as much space between analog and digital components as possible to prevent crosstalk from arising. Separation is typically done through planar partitioning of the PCB, and crosstalk is the electric or magnetic disturbance of a circuit due to a signal leakage. Crosstalk can also be reduced through a number of measures including: grouping logic families according to function, placing components close to each other, place components away from the I/O connector, isolate high noise emitters on their own layers, route adjacent layers orthogonally, and avoid traces parallel to each other[49]. By carefully setting up the PCB many problems caused by distortion can be solved before issues ever arise. The equation for determining crosstalk strength is listed below. “The constant K has to be less than 1 and depends upon the rise time of the circuit and length of the traces, H^2 is the product of the two heights of parallel traces, and D is the direct distance between the center line and traces”[49].

$$\text{Crosstalk} = K\,(H)^2 / (H^2 + D^2)$$

Equation: Crosstalk

3.15.3 Grounding

Grounding a circuit is a basic concept that every electric engineer learns in their first circuitry class however this concept becomes more complex when there has to be proper grounding for both analog and digital components in the same PCB. Issues arise when the complex impedance between two ground points have a current run through them. This current can travel across the ground impedance, and corrupt the signal at another point connected to a different ground shown in the figure below. This signal corruption is the result of ground noise partially or completely jamming the signal. This threat of a ground current is increased when a ground network contains loops or circular patterns. Thankfully there are a number of ways to reduce this issue, and one is already built into the PCB through the use of ground planes. These planes have a very low impedance reducing the noise inherently. Below are a few ways to reduce the noise and corruption caused by ground noise.

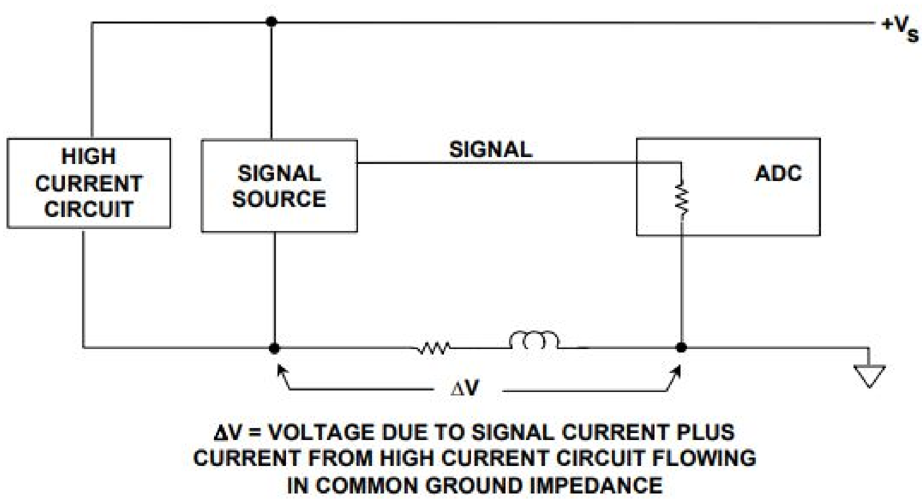


Figure 7: Ground Noise [permission pending][55]

3.15.4 Star Ground

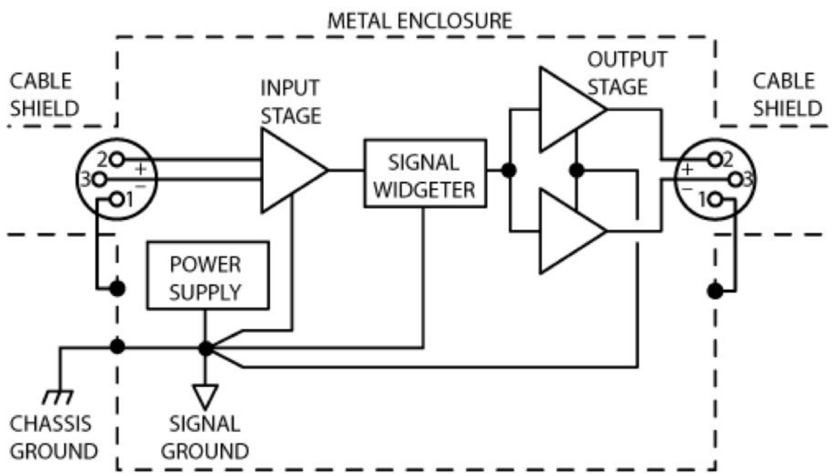


Figure 8: Star Grounding Example [Permission pending]

The star ground concept basically means that all points on a circuit are referenced back to a single ground point removing the possibility of a current to travel across the ground plane because there is no other ground point[55]. While this sounds like an easy solution to a complex problem it can be an extremely complicated concept to implement in complex circuits. The benefit of a star ground is typically overwritten by the problems caused by the extra tracing and extreme amount of vias to reach the star ground. This means that star grounding while being a good way to reduce ground current is ultimately not a feasible. A simple example of star grounding is shown above where all necessary ground points are connected to one ground

3.15.5 Partitioning of the Analog and Digital

An effective way to reduce ground noise is to partition the analog and digital components to their own ground plane and areas of the board as well as have their own power source. Doing this reduces the corrupt of the signals due to the ground noise, and also is a smart design choice because analog and digital components can interact negatively when placed close to each other on a board. ALso when doing this the two sides of the board have to be connected by an electro bead which is the only connection between the two boards. The planes that power the partitioned sections will be physically separated as well making one plane 3.3v and the other plane will be a pure 3 volts. These are the only two voltage planes that are needed for the circuit as any other necessary voltage can be achieve using these planes with dividers or other circuits.

3.15.6 Designing a Ground Isolation Amplifier

Another way to reduce ground noise is to add a ground isolating amplifier to the circuit. The amplifier's purpose is to reduce the error voltages by measuring the signal in a, "differential fashion"[55]. The use of these amplifiers essentially reject the CM voltages that are causing issue for the circuit. By using an amplifier you get a high impedance which results in a relatively low voltage drop reducing noise, and the differential fashion in which the signal is measured reduces the circuit's sensitivity to ground noise.

4.0 Research

4.1 Accelerometer Sensor Research

Accelerometers are devices that measure acceleration, which is the rate of change of the velocity of an object. They measure in meters per second squared (m/s^2) or in G-forces (g). A single G-force for us here on planet Earth is equivalent to 9.8 m/s^2, but this does vary slightly with elevation (and will be a different value on different planets due to variations in gravitational pull). Accelerometers are useful for sensing vibrations in systems or for orientation applications. Accelerometers are electromechanical devices that sense either static or dynamic forces of acceleration. Static forces include gravity, while dynamic forces can include vibrations and movement. [31] The accelerometer will be used to sense car theft and car damage from the vibrations and movements of acceleration forces. These acceleration forces will be tested and recorded in the accelerometer to distinguish scenarios of car theft and car damage from other scenarios of vibration and movement, such as when a car passes by, the car is being touched or bumped by bystanders, etc. and even false positives that can potentially trigger the device with the accelerometer. Gravity must also be taken into account when recording the results as it is an active acceleration force that will always affect the device and the accelerometer itself.

4.1.1 Accelerometer Connection

The accelerometer sensing is a fusing of electrical and mechanical components which allow machines to perceive movement by means of detecting acceleration. They do this most commonly by means of measuring the change in the position of mass. An analog signal is created by an interface module which is run through an analog-to-digital converter (ADC) to allow the signal to be utilized by a digital processor. The accelerometer works primarily by means of Newton's Second Law of Motion, which states that acceleration is equal to the sum of the forces on an object divided by the object's mass. [5] As such, the accelerometer sensor measures acceleration indirectly through force and knowing the precise mass of the moving portion of the sensor.

The communication interface of the accelerometer has three ways of communication: 1) Analog, 2) Digital, and 3) Pulse Width. Accelerometers with an analog interface show accelerations through varying voltage levels. These values generally fluctuate between ground and the supply voltage level. An ADC on a microcontroller can then be used to read this value. These are generally less expensive than digital accelerometers. Accelerometers with a digital interface can either communicate over SPI or I2C communication protocols. These tend to have more functionality and be less susceptible to noise than analog accelerometers. Accelerometers that output data over pulse-width modulation (PWM) output square waves with a known period, but a duty cycle that varies with changes in acceleration. [31] The analog interface must be looked into for issues in buffering and impedance. This is by far the single most common source of problems in projects involving analog accelerometers, because so few people thoroughly read the required documentation. Both PIC and AVR datasheets specify that for A-D conversion to work properly, the connected device must have an output impedance under 10 kΩ. [34] The input impedance must also be kept high while the output impedance needs to be kept low,so the output impedance must be under 10 kΩ, while the input impedance must be significantly higher than that. This helps preserve the signal levels and frequency responses, but if the input impedance doesn't become significantly higher than the output impedance, than the signal-to-noise ratio and frequency responses suffers as a result. A higher input impedance also ensures that circuits will interface with the accelerometer correctly that may not supply enough power and voltage and a low output impedance helps the accelerometer interface with circuits that require high input power and voltage.

Accelerometers are generally low-power devices. The required current typically falls in the micro (μ) or milli-amp range, with a supply voltage of 5V or less. The current consumption can vary depending on the settings (e.g., power saving mode versus standard operating mode). These different modes can make accelerometers well suited for battery powered applications. [31] This is beneficial to the SSDC device as the voltage required to operate the accelerometer is low which creates more room to power other components of the device as well. Tests will need to be done to test the voltage requirement that the accelerometer will operate in, especially during standard operating mode and power saving mode as they will implemented into the SSDC.

4.1.2 Accelerometer MEMS

What will be used is called a microelectromechanical systems (MEMS) accelerometer. Most typically, the structure of the MEMS accelerometer sensor is constructed as a variable capacitor. There are two common arrangements to create this variable capacitance. One form is called single-sided, the other is known as a differential pair. The single-sided is to have a fixed electrode and a moveable mass. The other arrangement, called a differential pair, is constructed such that there are two fixed plates with a defined area and specific distance between the two. A moveable mass is then placed between the two plates. Thus, the sensor actually works by detecting the displacement of the moveable mass. The mass is displaced by micrometers, caused by the acceleration of the sensor, which creates an extremely small change in capacitance.

For both arrangements, the orientation of the set of plates are as such as the plates are perpendicular to the motion that is being measured. Both of these sensors are designed such that there is a spring between the plates which centers the moveable mass after movement is detected. The plates, or electrodes, are created from silicon substrates. These variable capacitor-type sensors are known for being highly accurate, having good stability, dissipating low power, are not susceptible to noise and variations in temperatures, and are simple to construct. They have a limiting bandwidth of only a few hundred Hertz due to the construction utilizing springs and trapped air within the IC which acts as a damper.

Because the sensor's change in capacitance is so small, it is suggested to use multiple movable and fixed plates connected in parallel with one another. This typically results in a large structure of fixed electrodes and moving plates in a large parallel array for the most accuracy. Many manufactured accelerometers have at least 8 moving electrodes that move in relation to fixed plates which are connected to sense the change in capacitance. For multi-axis sensors, these arrayed sensors can be mounted orthogonally to one another in a single unit such that one sensor array senses acceleration in the X-direction, one in the Y-direction, and the final one senses acceleration in the Z-direction. Another option for the construction of multi-axis accelerometers is to use one moveable mass with fixed plates in an arrangement such that the mass can move in two axis.

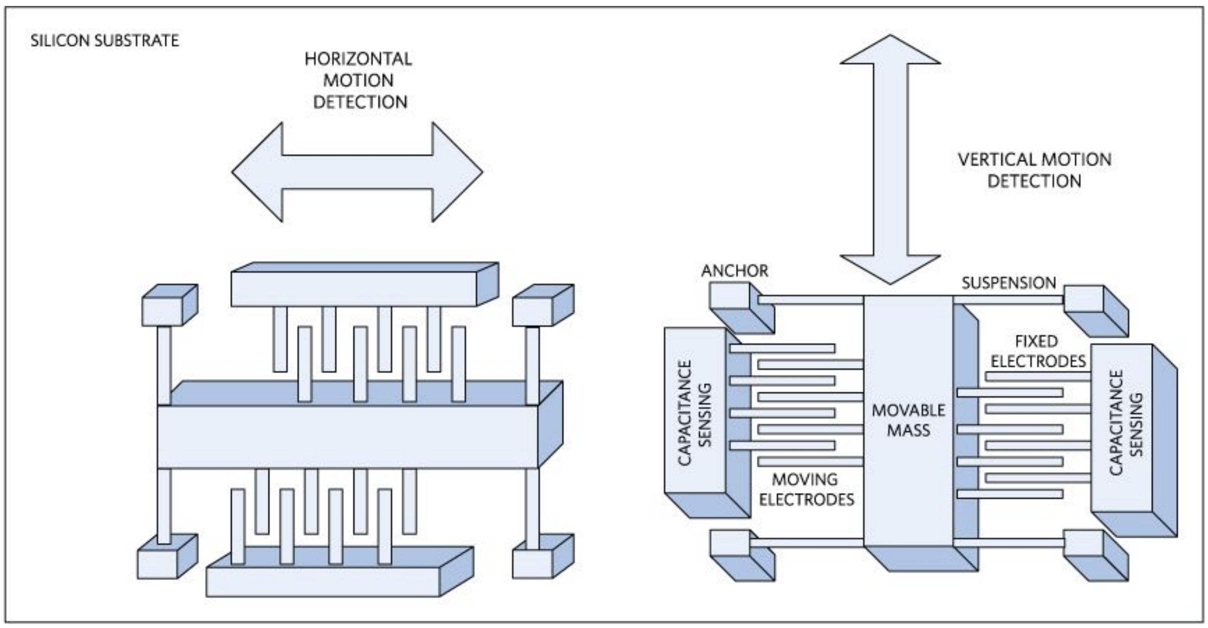


Figure 9: 2-Axis Accelerometer (Permission Pending) [65]

One aspect of MEMS accelerometers that will be beneficial to the SSDC is condition monitoring. Condition monitoring is the process of monitoring the state of the machine or device while it is in operation. This type of monitoring observes machine condition such as vibration, temperature, etc. This benefits the use of the SSDC for future maintenance but also to prevent failures and avoid consequences. For accelerometers and the purpose of this device, detecting vibrations is essential for detect car theft and car damage.

Solid-state electronics can impact the size of the transducer. A smaller form factor triaxial mounted on a printed circuit board (PCB) and inserted into a hermetic housing suitable for mounting and cabling on a machine, can help enable a smaller overall package, offering more mounting and placement flexibility on the platform. In addition, today's MEMS devices can include significant amounts of integrated, single voltage supply signal conditioning electronics, providing analog or digital interfaces with very low power to help enable battery-powered wireless products. For example, the ADXL355, a high resolution, high stability triaxial accelerometer has an integrated Σ-Δ analog-to-digital converter (ADC), with an effective resolution of 18 bits and an output data rate of 4 kSPS, and consumes less than 65 µA per axis. [36] Having signal conditioning supports ADC as the signal can be manipulated in a way that prepares an analog signal to be processed and converted into a digital signal. This type of conditioning is also used for conditions in vibration, temperature, etc., which will be useful when using the accelerometer for vibration detection and having the analog voltage signals be converted into digital value signals for acceleration forces. The use of low power for the accelerometer will also support the SSDC to be able to operate and function with the accelerometer at low voltage requirements.

The topology of a MEMS signal conditioning circuit with both analog and digital output variations is common and opens up options for the transducer designer to adapt the sensor to a wider variety of situations, enabling a transition to digital interfaces commonly available in industrial settings. For example, RS-485 transceiver chips are widely available and open market protocols, such as Modbus RTU, are available to load into an adjacent microcontroller. A complete transmitter solution can be designed and laid out with small footprint surface-mount chips that can fit within relatively small PCB areas, which can then be inserted into packages that can support environmental robustness certifications requiring hermetic or intrinsically safe characteristics. [36] This will support the PCB design of the SSDC device as it needs to be relatively small enough to fit behind the rear view mirror and meet the requirement specifications of the device's dimensions.

A MEMS has demonstrated to be very robust to changes in the environment, as well. The shock specifications of today's generation of devices are stated to 10,000 *g*, but in reality can tolerate much higher levels with no impact on sensitivity specifications. Sensitivity can be trimmed on automatic test equipment (ATE) and designed and constructed to be stable over time and temperature to 0.01°C for a high resolution sensor. Overall operation, including offset shift specifications, can be guaranteed for wide temperatures ranges, such as −40°C to +125°C. For a monolithic triaxial sensor with all channels on the same substrate, cross axis sensitivity of 1% is commonly specified. Finally, as a device designed to measure the gravity vector, a MEMS accelerometer has a dc response, maintaining the output noise density to near dc, limited only by the 1/f corner of the electronic signal conditioning and, with careful design, can be minimized to 0.01 Hz. [37] The environmental robustness will support the testing scenarios and the purpose of the SSDC device when undergoing cases of car theft and car damage, especially in extreme cases of car damage where the acceleration forces can be very high. Being temperature tolerant will also benefit the use of the SSDC device when functioning inside a car as it can reach high temperatures. A wide range of temperature tolerance for the accelerometer is needed to be able to operate and function under high and low temperatures. Sensitivity stability and output noise density kept at DC levels supports more accurate readings of large changes in signal.

Perhaps one of the biggest advantages of MEMS-based sensors is the capability to scale up manufacturing. MEMS vendors have been shipping high volumes for mobiles, tablets, and automotive applications since 1990. This manufacturing capability residing in semiconductor fabrication facilities for both the MEMS sensor and the signal conditioning circuit chip is available to industrial and aviation applications as well, helping to lower the overall cost. Moreover, with more than a billion sensors shipped for automotive applications over the last 25 years, the reliability and quality of MEMS inertial sensors have been demonstrated to be very high. MEMS sensors have enabled complex crash safety systems that can detect crashes from any direction and appropriately activate seat belt tensioners and airbags to protect occupants. Gyroscopes and high stability accelerometers are also key sensors in vehicle safety controls. Today's automotive systems make extensive use of MEMS inertial sensors to enable safer, better handling cars at low cost and excellent reliability. [36] Since MEMS technology has been tested in crash safety systems and crash detections, this will be reliable when using the MEMS technology for the accelerometer in the SSDC device when testing for car crash scenarios. This also supports the function of the SSDC device as it is made to detect instances of car theft and car damage and notify the user of such.

4.1.3 Accelerometer Sensitivity

An accelerometer can be distinguished by a few features, these features will determine what the proper sensor for the application is. One of the key features is that of sensitivity. This sensitivity is rated in millivolts per gram (mV/g), and is a metric of the minimum change or movement of the physical mass that will produce a detectable signal. The sensitivity is only valid for one frequency, and not a range of frequencies. The range of frequencies an accelerometer functions within is considered the Bandwidth, which is measured in Hertz (Hz). The bandwidth is a realistic range of vibration frequencies in which the accelerometer will produce reliable signals. The bandwidth can also be the frequency in which you can take a reliable reading from the sensor. The bandwidth is also associated with the frequency response which is measured in Hertz (Hz). This, like bandwidth, is a frequency range which the sensor will give a true signal that signifies the proper detection of motion. The frequency response typically has a tolerance range. In a similar vein, the dynamic range of the sensor is the range between the smallest possible motion that will incur a true detection signal to the largest possible movement that will take place right before saturating the output signal which would result in clipping and distortion of the detection signal.

An important characteristic of accelerometer sensors is what's called the voltage noise density, which is a function of the voltage from noise and the inverse-square root of the bandwidth.This states that the faster an accelerometer is read, the lower the accuracy for the sensor becomes. The more often the changes of an accelerometer are read, the larger the effects of noise become. This is exacerbated in lower-gravity situations. Such as zero-g situations. The zero-g voltage is a phrase that makes the voltage output under 0g acceleration, or no acceleration in the X and Y directions. [8]

4.1.4 Accelerometer Vibration Detection

Vibration is the movement or mechanical oscillation about an equilibrium position of a machine or component. It can be periodic, such as the motion of a pendulum, or random, such as the movement of a tire on a gravel road. Vibration can be expressed in metric units (m/s2) or units of gravitational constant “g,” where 1 g = 9.81 m/s^2. [35] The accelerometer will be used to detect vibrations during cases of car passing by on the road or parking areas or cases of vibrations caused by car theft. These vibrations must be distinguished from one one another in order for the accelerometer to trigger the SSDC device during cases of car theft and car damage and ignore cases of vibrations that can potentially cause false positives such as movement in the tires of a car. There are two types of vibration: free vibration and forced vibration.

Free vibration occurs when an object or structure is displaced or impacted and then allowed to oscillate naturally. For example, when you strike a tuning fork, it rings and eventually dies down. Natural frequency often refers to the frequency at which a structure “wants” to oscillate after an impact or displacement. Resonance is the tendency for a system to oscillate more violently at some frequencies than others. [35] These type of vibrations can be caused by minor bumps or hits to the car, or even vibrations to the tires of the car from cars passing by or the ground moving slightly and eventually die down. These type of vibrations should be ignored as they are not proper scenarios to trigger the SSDC device. However, if constant free vibrations occur during cases of car theft where the amplitude of the vibration stays the same over time then dies down, then this must be tested and recorded as the SSDC device will need to be triggered during these types of cases of free vibrations. Other cases of free vibrations must also be filtered out if the change in vibration is minor or if the scenario causing a free vibration does not qualify as an event that should cause the accelerometer to trigger the SSDC device.

Forced vibration at or near an object’s natural frequency causes energy inside the structure to build. Over time the vibration can become quite large even though the input forced vibration is very small. If a structure has natural frequencies that match normal environmental vibration, then the structure vibrates more violently and prematurely fails. Forced vibration occurs when a structure vibrates because an altering force is applied. Rotating or alternating motion can force an object to vibrate at unnatural frequencies. An example of this is imbalance in a washing machine, where the machine shakes at a frequency equal to the rotation of the turnstile. In condition monitoring, vibration measurements are used to indicate the health of rotating machinery such as compressors, turbines, or pumps. These machines have a variety of parts, and each part contributes a unique vibration pattern or signature. By trending different vibration signatures over time, you can predict when a machine will fail and properly schedule maintenance for improved safety and reduced cost. [35] Sudden acceleration forces of car theft and car damage can cause a forced vibration to occur, and the accelerometer would need to detect these type of vibration and trigger the SSDC device. Further testing and recording of these type of vibrations are needed during these scenarios to have the accelerometer trigger the device during these cases. However, these types of vibrations can also occur when the vehicle is active and when the user is driving their vehicle. Forced vibrations can occur when sharp turns or sudden motions of the car are made by the user that would not be considered as events to trigger the device. Different parts of the car at different frequencies and vibrations can also cause forced vibrations if their is an imbalance in the vehicle. These types of scenarios in forced vibrations must be tested and recorded to filter them out in the accelerometer to prevent false positives to trigger the device.

Most accelerometers rely on the use of the piezoelectric effect, which occurs when a voltage is generated across certain types of crystals as they are stressed. The acceleration of the test structure is transmitted to a seismic mass inside the accelerometer that generates a proportional force on the piezoelectric crystal. This external stress on the crystal then generates a high-impedance, electrical charge proportional to the applied force and, thus, proportional to the acceleration. Piezoelectric or charge mode accelerometers require an external amplifier or inline charge converter to amplify the generated charge, lower the output impedance for compatibility with measurement devices, and minimize susceptibility to external noise sources and crosstalk. Other accelerometers have a charge-sensitive amplifier built inside them. This amplifier accepts a constant current source and varies its impedance with respect to a varying charge on the piezoelectric crystal. These sensors are referred to as Integrated Electronic Piezoelectric (IEPE) sensors. Measurement hardware made for these types of accelerometers provide built in current excitation for the amplifier. [35] The use of the piezoelectric crystals applies to the use of the accelerometer and the SSDC device as they will undergo mechanical stress during scenarios of car theft and car damage and other scenarios that will cause vibrations on the vehicle and the device. Another alternative in measuring the acceleration forces in an accelerometer is the use of internal capacitive plates. In this case, the plates can either be fixed or be attached to miniscule springs that will move internally when acceleration forces are acted upon the sensor. The movement of these plates cause a change in capacitance, and from this change the acceleration forces can be determined in the accelerometer.

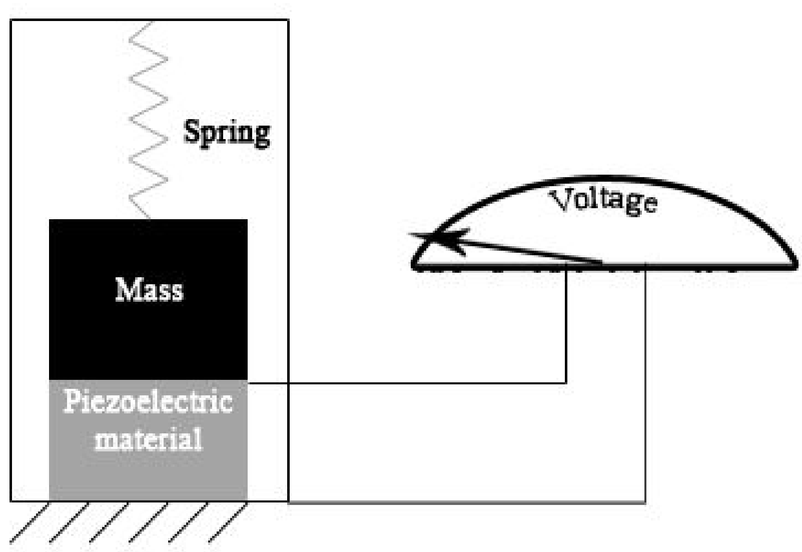


Figure 10: Example of a piezoelectric accelerometer [31]

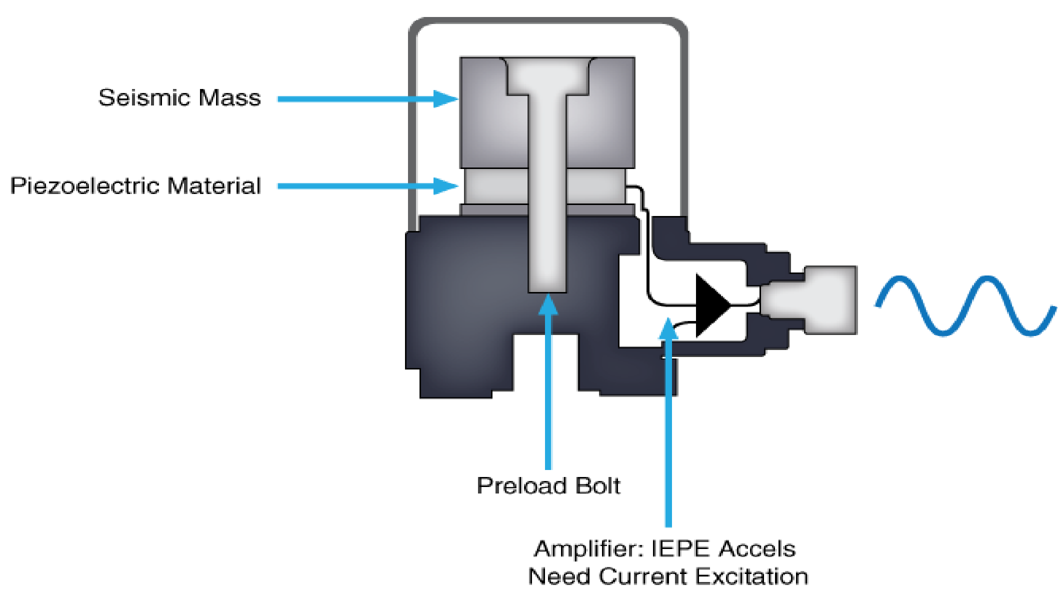


Figure 11: IEPE accelerometers output voltage signals proportional to the force of the vibration on the piezoelectric crystal. (Permission Pending) [35]

4.1.5 Accelerometer X, Y, and Z Axis

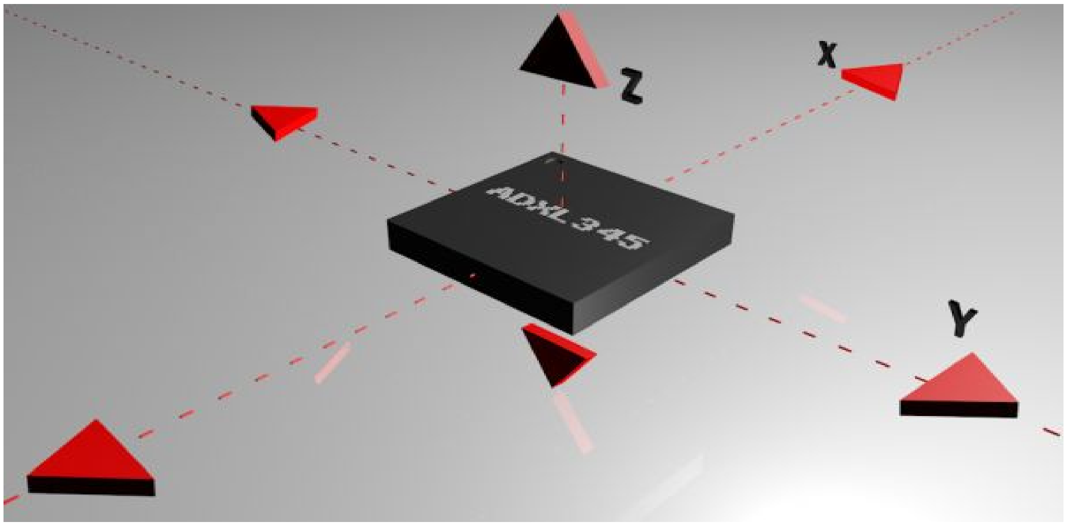


Figure 12: Example of axes of measurement for a triple axis accelerometer (Permission Granted by SparkFun) [31]

The accelerometer can support up to a 3D axis plane to detect acceleration forces. For the SSDC device, three axes must be used in order to detect acceleration forces on the car from all sides. The position of the 3D plane of axes must be checked as to better record values that are positive or negative to know the direction of where the acceleration force is coming from. The X- or Y- axes can be considered to be front or sides of the car and acceleration forces from either left or right or forward and backward can be distinguished with positive and negative value. Gravity must also be taken into account as it will most likely affect the Z-axis of the accelerometer, most likely causing a negative acceleration force downwards on to the vehicle. If the vehicle were lifted slightly or driving or parked uphill, tthe a change in the acceleration forces in the Z-axis can occur. These acceleration forces in the 3D axis plane must will be recorded when the user is driving their vehicle and when the vehicle is parked and the vehicle is inactive. The changes in acceleration forces can occur when the vehicle is driving either in a straight motion, during turns, or when a car crash occurs. The vehicle when parked and inactive must be currently in a constant state and the sudden changes in acceleration forces can be recorded.

Most accelerometers will have a selectable range of forces they can measure. These ranges can vary from ±1g up to ±250g. Typically, the smaller the range, the more sensitive the readings will be from the accelerometer. For example, to measure small vibrations on a tabletop, using a small-range accelerometer will provide more detailed data than using a 250g range (which is more suited for rockets). [31] The ranges selected for the accelerometer must be good enough to detect vibrations or sudden changes in acceleration from other acceleration forces that count as car theft and car damage.

4.1.6 Accelerometer Sensor Selection

There are multiple characteristics when selecting an accelerometer, as they are versatile with varying sizes, designs, and ranges. The requirement specifications must be considered when selecting the accelerometer. Characteristics that need to be considered are vibration amplitude, sensitivity, number of axes, weight, mounting options, environmental constraints, and cost.

The maximum amplitude or range of the vibration you are measuring determines the sensor range that you can use. If you attempt to measure vibration outside a sensor's range, it distorts or clips the response. Typically, accelerometers used to monitor high vibration levels have a lower sensitivity and lower mass. [35] The range of detecting the vibrations must meet the requirements of detecting car theft and car damage. This range can be determined by the the amount of acceleration force that car theft and car damage caused to the vehicle.

Sensitivity is one of the most important parameters for accelerometers. It describes the conversion between vibration and voltage at a reference frequency, such as 160 Hz. Sensitivity is specified in mV per G. If typical accelerometer sensitivity is 100 mV/G and you measure a 10 G signal, you expect a 1000 mV or 1 V output. The exact sensitivity is determined from calibration and usually listed in the calibration certificate shipped with the sensor. Sensitivity is also frequency dependent. A full calibration across the usable frequency range is required to determine how sensitivity varies with frequency. In general, use a low sensitivity accelerometer to measure high amplitude signals and a high sensitivity accelerometer to measure low amplitude signals. [35] Small and high vibrations levels need to be detected as scenarios of car theft and car damage must be detected to trigger the device and the accelerometer must also be able to filter out any scenarios that can cause false positives or are not valid triggers for the SSDC device. A middle ground must be made in order to detect high and low amplitude signals.

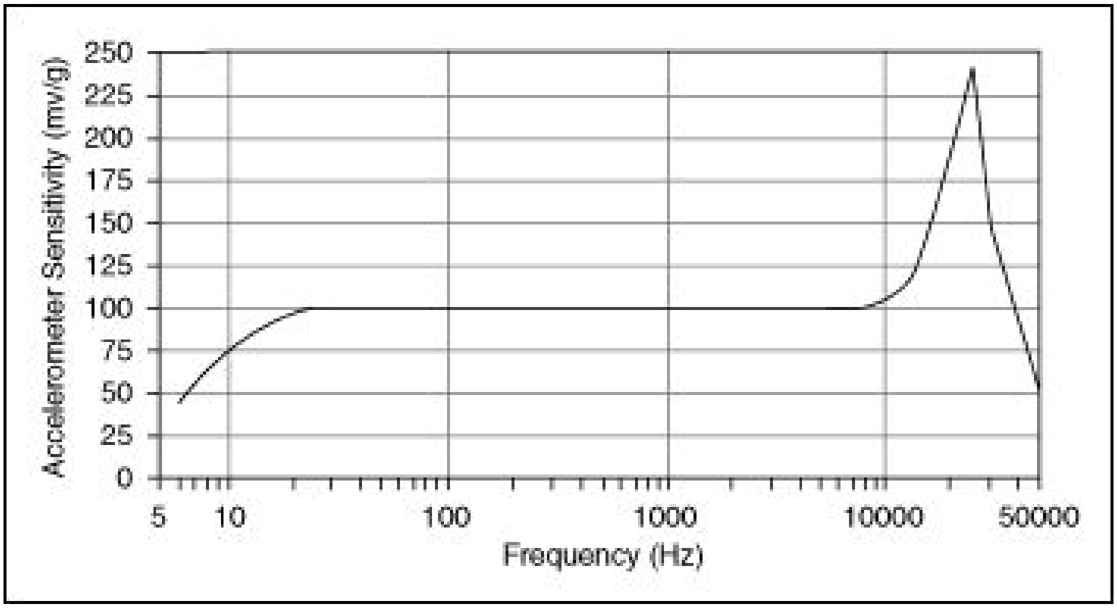


Figure 13: Accelerometers have a wide usable frequency range where sensitivity is relatively flat. (Permission Pending) [35]

The user can choose from two axial types of accelerometers. The most common accelerometer measures acceleration along only a single axis. This type is often used to measure mechanical vibration levels. The second type is a triaxial accelerometer. This accelerometer can create a 3D vector of acceleration in the form of orthogonal components. Use this type when you need to determine the type of vibration, such as lateral, transverse, or rotational. [35] The accelerometer used should be 3D axis as the SSDC will need to measure the acceleration forces from all sides of the vehicle. The triaxial accelerometer can be beneficial for the SSDC device as it helps detect specific scenarios such as car theft and car damage to properly trigger the SSDC device and filter out any occurrences that may cause false positives or aren't a valid trigger to the device.

Accelerometers should weigh significantly less than the structure you are monitoring. Adding mass to the structure can alter its vibrational characteristics and potentially lead to inaccurate data and analysis. The weight of the accelerometer should generally be no greater than 10 percent of the weight of the test structure. [35] The accelerometer that will be used for the SSDC device will generally weigh less and must be of minimal mass in comparison to device to have accurate recording of acceleration forces. This should not be a major issue as the accelerometer chips available for use in the SSDC device are generally small and weigh very little in comparison to the whole device that will be used.

Another consideration for your vibration measurement system is how to mount the accelerometer to the target surface. You can choose from four typical mounting methods: 1) Handheld or probe tips, 2) Magnetic, 3) Adhesive, and 4) Stud mount. Stud mounting is by far the best mounting technique, but it requires you to drill into the target material and is generally reserved for permanent sensor installation. The other methods are meant for temporary attachment. The various attachment methods all affect the measurable frequency of the accelerometer. Generally speaking, the looser the connection, the lower the measurable frequency limit. The addition of any mass to the accelerometer, such as an adhesive or magnetic mounting base, lowers the resonant frequency, which may affect the accuracy and limits of the accelerometer's usable frequency range. Consult accelerometer specifications to determine how different mounting methods affect the frequency measurement limits. [35] The SSDC device should have the accelerometer be stud mounted onto the device to provide a secure connection and have a high frequency limit. The accelerometer should also be permanently attached inside of the hardware of the device, as the typical user will not be concerned with removing the accelerometer from the device, nor will they be concerned with the inside of the hardware. Only the requirements specification must be met in order for the accelerometer to operate and function within the device. Other methods of mounting will not be used for the final SSDC device creation.

Method	Frequency Limit
Handheld	500 Hz
Magnetic	2,000 Hz
Adhesive	2,500 to 5,000 Hz
Stud	> 6,000 Hz

Table 1: Frequency Limits for Mounting a 100 mv/G Accelerometer. (Permission Pending) [35]

When choosing an accelerometer, pay attention to critical environmental parameters such as maximum operating temperature, exposure to harmful chemicals, and humidity. Most accelerometers can be used in hazardous environments because of their rugged and reliable construction. For additional protection, industrial accelerometers built from stainless steel can protect the sensors from corrosion and chemicals. A charge mode accelerometer can be used if the system must operate in extreme temperatures. Since these accelerometers do not contain built-in electronics, the operating temperature is limited only by the sensing element and materials used in the construction. However, since they do not have built-in conditioning and charge amplification, charge mode accelerometers are sensitive to environmental interference and require low-noise cabling. If the environment is noisy, the accelerometer should use an inline charge converter or IEPE sensor with a built-in charge amplifier. Humidity specifications are defined by the type of seal an accelerometer has. Common seals include hermetic, epoxy, or environmental. Most of these seals can withstand high levels of moisture, but a hermetic seal is recommended for fluid immersion and long exposure to excessive humidity. [35] The environment of the accelerometer in the SSDC device will be on the back of a rear-view mirror inside the user's vehicle. The vehicle will be exposed to high temperatures as cars can generally become more hot when placed under sunlight over time. This mean that the accelerometer needs to have a wide range for temperature tolerance to operate and function in the device. Since the environment will potentially be noisy as the accelerometer will also detect vibrations caused by car theft and car damage, including vibrations caused by bumping or hits and shaking in the ground to the tires by cars passing by, the noise should be handled to prevent inaccurate readings of acceleration forces. Fortunately, the MEMS technology provides sensitivity stability and keeps the output noise density at DC levels to allow accurate readings and prevent constant changes in the measurement of the vibrations and acceleration forces.

Although charge mode and IEPE accelerometers have similar costs, IEPE accelerometers have a significantly lower cost for larger, multichannel systems because they do not require special low-noise cables and charge amplifiers. In addition, IEPE accelerometers are easier to use because they require less care, attention, and effort to operate and maintain. [35] A low cost accelerometer is needed as the SSDC device will be composed of multiple devices necessary to detect car theft and car damage and filter out any false positives or instances of vibrations that should not trigger the device. There are accelerometers with a lot of features and have parameters that meet the requirements specifications of the project, but are costly. The accelerometer should be good enough to reach the requirements specifications and have low cost when selected for the device. The features in the accelerometer selected should only support the function and purpose of the device.

The project will only require the sensing of acceleration in the horizontal plane direction as well as the vertical plane, so an X, Y, and Z axis accelerometer will be utilized. The two main characteristics are its sensitivity, and its operating temperature. As it will be in a vehicle, the interior will get increasingly hot the longer it is outside, especially in Florida. Temperatures can range up to 172°F (77.78°C) [7], as such ideally the sensor should be able to handle temperature ranges in excess of 81°C for a 5% margin for error. The sensitivity of the sensor has to be sufficient enough such that it will be able to accurately detect when the vehicle is moved while parked. These sensors can be either analog, meaning it outputs a specific voltage given a sensed acceleration, or digital meaning the sensor has a subsystem which involves feeding the analog output of the sensor into an on-board analog-to-digital (ADC) circuit, a filter, and a serial input/output unit. These types of sensors are handy for use with things such as microcontrollers and other digital processing systems. The sensitivity of these type of sensors are given in terms of units per least significant bits (LSB) such as mg/LSB, or milli-gravity per LSB.

Part Number	Axis	Temperature Range	Maximum Temperature Range	Resolution	Sensitivity
ADXL345	3-Axis	-40°C - +85°C	105°C	±2g	3.9 mb/LSB
				±4g	7.8 mg/LSB
				±8g	15.6 mg/LSB
				±16g	31.2 mg/LSB
LSM9DS0	3-Axis	-40°C - +85°C	105°C	±2g	0.061 mb/LSB
				±4g	0.122 mg/LSB
				±6g	0.183 mg/LSB
				±8g	0.244 mg/LSB
				±16g	0.732 mg/LSB

Table 2: Accelerometer Sensor Comparison

4.2 Gyrometer Sensor Research

Gyrometers function in a very similar way to accelerometers. However, while accelerometers detect in a linear motion, gyrometers detect movement in a rotational way, around a specified axis. These axis are typically named the yaw, roll, and pitch axis. The axis' name depends on how the gyrometer sensor is mounted, and not defined by a universal spatial standard, such as the X, Y, and Z axis. Most typically, the roll axis is the axis that goes in the center of the object in the direction of motion. The yaw is perpendicular to the roll axis and describes twisting motion on the horizontal plane, meaning rotational motion left or right of the direction of motion. The pitch axis is again perpendicular to both of the previous axes and typically describes the motion of the body up and down, in reference to the horizontal plane of motion.

4.2.1 Gyrometer Connection

Gyros can have either a *digital* or *analog* communication interface. Gyros with a *digital* interface usually use either the SPI or I2C communication protocols. Using these interfaces allow for an easy connection to a host microcontroller. One limitation of a digital interface is max sample rate. I2C has a max sample rate of 400Hz. SPI, on the other hand, can have a much higher sample rate. Gyros with an *analog* interface represent rotational velocity by a varying voltage, usually between ground and the supply voltage. An ADC on a microcontroller can be used to read the signal. Analog gyros can be less expensive and sometimes more accurate, depending on how you are reading the analog signal. [12] The digital and analog communication interface will be used for the SSDC as samples of angular speeds need to be taken to filter out false positives and trigger properly during scenarios of car theft and car damage to the device. For this, the ADC will be used on the microcontroller to simulate the measurements of the angular speed of the vehicle from the device to make measurements of reads of the car's current and changing angular velocity.

4.2.2 Gyrometer MEMS

Much like the accelerometer, the gyrometer that will be used is a MEMS gyrometer. The MEMS gyrometer is constructed differently than the MEMS accelerometer, but uses the same effect of sensing the change in capacitance by having fixed plate electrodes and moving electrodes that move with a mass. However, gyrometers are constructed of three sub frames. The outermost frame is constructed with fixed plate electrodes on two opposite sides. Within the frame is an inner frame which has moving electrodes on its perimeter that interact with the outside frame's fixed electrodes, thus these electrodes are nested in between the fixed plates of the outside frame. The inner frame is connected to the outside frame by springs which center it in the middle. These springs are connected to the two sides that have no electrodes, such that there is no axial motion of the plates. Nested within the inner frame is a specific mass which acts as the catalyst for motion. This mass is connected to the inner frame by two springs, which are orthogonal to the springs which connect the inner frame to the other frame. Thus, as the mass resonates, the energy is transferred to the inner frame which then changes the capacitance in the sensing electrode plates on the outer frame which is thus read as a signal.

MEMS gyros are generally low power devices. Operating currents are in the mA and sometimes a microA range. The supply voltage for gyros is usually 5V or less. Digital gyros can have selectable logic voltages or operate at the supply voltage. For any digital interface, remember to connect 5V to 5V lines and 3.3V to 3.3V lines. Also, gyros with digital interfaces can have low power and sleep modes that allow them to be used in battery powered applications. Sometimes this is an advantage over an analog gyro. [12] These low power devices will be beneficial in supply voltage to gyrometer along with many other components on the SSDC. A low power and sleep mode will be used as the vehicle will be active when the user is driving their vehicle and be inactive when the vehicle is parked by the user.

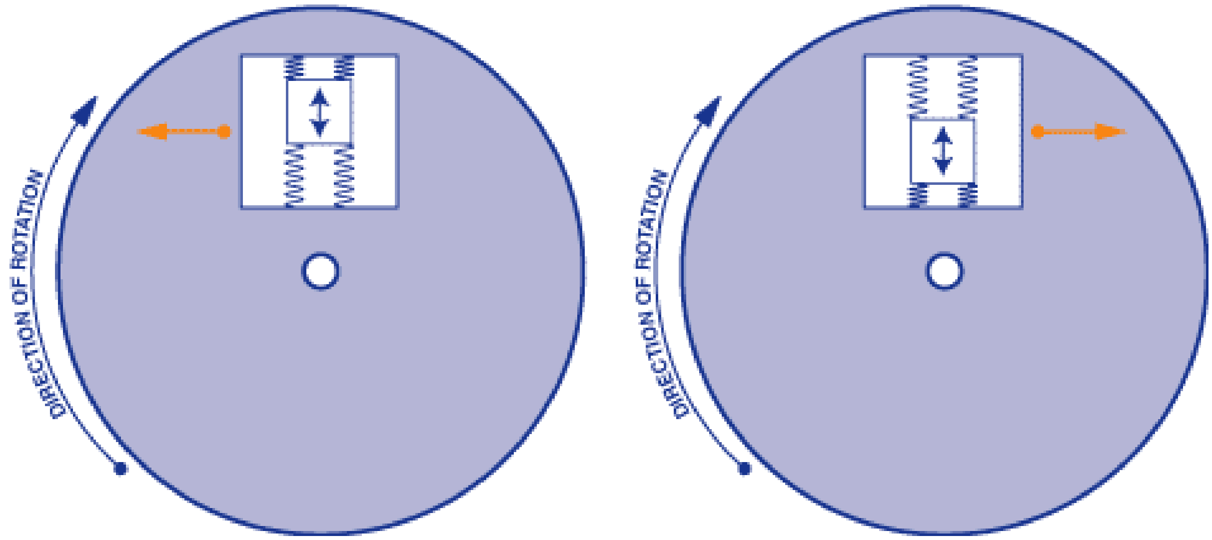


Figure 14: Internal operational view of a MEMS gyro sensor (Permission Granted by SparkFun) [12]

4.2.3 Gyrometer Rotation Detection

The functionality of the gyrometer, much like the accelerometer, detects rotational motion by means through measure of an acceleration. The acceleration that is measured is called the Coriolis acceleration. The Coriolis acceleration is the acceleration due to a spinning and translating reference frame, which the inner-frame of the MEMS gyrometer acts as. The necessary variables to find the Coriolis acceleration is the rotational velocity of a rotating body and the velocity of the object within the rotating body. Thus, by measuring the Coriolis acceleration, we can find the rotational velocity. This means of measurement is the same effect as Foucalt's pendulum, in which a swinging or vibrating mass is displaced axially due to rotation of the connecting body. [10]

4.2.4 Gyrometer X, Y, and Z Axis

A triple axis MEMS gyroscope can measure rotation around three axes: x, y, and z. Some gyros come in single and dual axis varieties, but the triple axis gyro in a single chip is becoming smaller, less expensive, and more popular. [12] A triple axis gyroscope will be need as the vehicle's angular velocities need to be measured on all sides, which requires a 3D plane measurement. The direction, or in the case of measuring the angular velocities either positive or negative measurements, must be considered when recording the data from the hardware and software code as well as the range of values that can be measured as well.

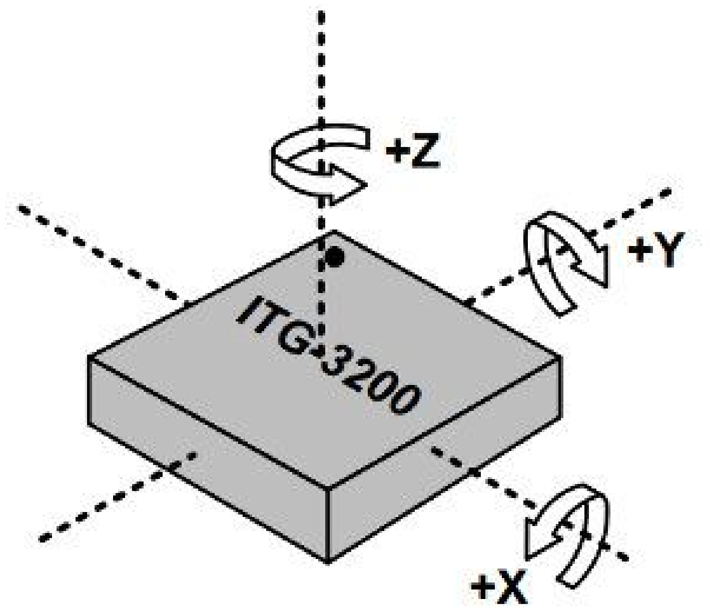


Figure 15: Example of axes of measurement for a triple axis gyrometer (Permission Granted by SparkFun) [12]

4.2.5 Gyrometer Sensor Selection

Selecting a gyrometer that is correct for the application is important, and as such metrics should be defined to better understand and have the ability to compare the sensors. Some basic characteristics that should be taken under consideration. One of these characteristics is what should be called the range of the sensor. That is, the angular velocity range in which the sensor can accurately detect. As such, ideally this would be the minimum angular velocity which should be detected and act as a true trigger, as well as the maximum range in which would be just outside the possibility of this application. Another such characteristic to be considered is that of the error that's inherent in the sensor. The aim for this should be zero, however for real applications this is not so. Some causes of bias errors would include bias drift, which is the tendency of a gyrometer to in accurately detect change in angular velocity [11], as well as changes due to temperature. These errors are typically well documented, and when integrated with other sensors, these errors can be reduced. The final characteristic to take into account is the sensitivity of the sensor. The sensitivity is given as millivolts per degree per second (mV/°/s), and thus is the amount the voltage the sensor produces given the angular velocity. This has to be sufficiently large such that the controller that's used can detect the changes accurately enough to make accurate and precise reactions. [12]

Part Number	Axis	Temperature Range	Maximum Temperature Range	Resolution	Sensitivity
BMG160	3-Axis	-40°C - +85°C		±125°/s	16.4 LSB/°/s
				±250°/s	32.8 LSB/°/s
				±500°/s	65.6 LSB/°/s
				±1000°/s	131.2 LSB/°/s
				±2000°/s	262.4 LSB/°/s
LSM9DS0	3-Axis	-40°C - +85°C	105°C	±245°/s	8.75 LSB/°/s
				±500°/s	17.5 LSB/°/s
				±2000°/s	70 LSB/°/s

Table 3: Gyrometer Sensor Comparison

4.3 Magnetometer Sensor Research

Magnetic fields are an accumulation of varying magnetic forces. These magnetic forces are created by things such as magnetic elements and electrical currents. Magnetic forces interact, and are affected by everyday items. The magnetic field passes through materials and is altered by what's called the material's relative permeability. The magnetic field strength (H) is given by the equation: $H = \mu_m B$ Where B is the magnetic field, and μ_m is the material's relative permeability. As such, when the field passes through different materials, the strength of the magnetic field changes. The magnetic field is also affected by other magnetic fields, which can be caused by electrical currents. This includes the human body, which produces its own magnetic field. The magnetic field that passes through a given point in space and time is called the flux. The flux is a vector, insomuch that there is a magnitude, or strength, of the magnetic field, and the direction of that field. [13]

4.3.1 Magnetometer Sensitivity

The magnetometer sensor detects the magnetic field in its surrounding area. There are two basic forms of magnetometers. The first is known as a scalar sensor. These sensors only detect the strength of the flux which passes through the sensor. The other type of sensor is a vector sensor. These types of sensors detect not only the magnitude of the magnetic field, but also the direction of the flux. [14] A simple example of a sensor is a simple coil wire, which, in the presence of a magnetic field, would create an electric current. This would not be able to detect the direction of the magnetic field, but would be able to determine the strength of the magnetic field. A popular construction methodology is to use what's called Hall Effect sensors. These sensors pass a continuous current through a silicon semiconductor. In the presence of a magnetic field, some of the charge is deflected to the sides of the semiconductor which is then detected as voltage. [15]

4.3.2 Magnetometer MEMS

A more complex construction example is that of MEMs-based designs. MEMs-based magnetometer sensors use Lorentz-Forces. A Lorentz force is a force caused by an electrical charge and a magnetic field. The equation that describes this, $F = qE + qv \times B$, where 'q' is a charged particle, 'E' is the electric field, 'v' is the velocity of the charged particle 'q', and 'B' is the magnetic field. [17] As such, the force the MEMs-based magnetometer detects is a function of both the electric charge received and the magnetic field it's undergoing. Thus, the sensor finds the magnetic field through indirect means by the forces applied to the internals of the sensor. These MEMs-based magnetometers send an AC signal to it's components, thus all of the variables within the Lorentz-Force equation is known except for 'B'. Once force is sensed, B can then be solved by computation. MEMs-based magnetometers also sense the magnetic field by means of capacitance. This is done by sensing the differentiating capacitance in a linear array of capacitor elements within the sensor. As the magnetic field passes through these capacitors, the capacitors slightly charge or discharge based on the field. As such, a further layer of detection is added. These sensors can be put in an orthogonal configuration to get a 2-dimensional mapping, or a 3-dimensional mapping of the magnetic field. Thus the sensor is able to give a vector read out of the field. [18]

4.3.3 Magnetometer Sensor Selection

Similar to all sensors, choosing the correct sensor for the application is important. As such, metrics are put in place to help determine which is the best choice given the environment it will be subject under, and the necessity of the sensor. Some of these characteristics include the sensitivity to the magnetic field, the hysteresis or range in which no discernable difference in the field is detected, how linear the response to the change in the magnetic field the sensor is. Another important measurement to take into account is the noise of a sensor. This has the capability of giving a false-positive report, or even a false negative if the amount of noise the sensor is subject of is large enough such that the threshold is too large and masks an actual change that would be necessary. The dynamic range of the sensor is also an important unit to keep in mind, as this will determine the distance at which the sensor can accurately detect changes in the field. If this range is too large, there's a risk that changes that are not associated with what should be monitored. If the range is too small, then it might not react strongly to an event that should be watched. These values have to be optimized to receive the best results while taking the magnetic field into account.

Within the LSM9DS0 is a magnetometer which, along the lines of the digital accelerometer and digital gyrometer have measurement ranges. The ranges associated with the magnetometer within the LSM9DS0 is ±2, ±4, ±8, ±12 gauss. Within these ranges, the sensitivity are as followed: For ±2 gauss, the sensitivity is 0.08 mgauss/LSB, for ±4 range it's 0.16 mgauss/LSB, for the ±8 range it's 0.32 mgauss/LSB, and for the ±12 gauss range it's 0.45 mgauss/LSB.

Whichever sensor is used must be put into various environments inside of a vehicle to test to find the appropriate range, such that the sensitivity will still be beneficial to sensing.

Part Number	Temperature Range	Maximum Temperature Range	Resolution	Sensitivity
LSM9DS0	-40°C - +85°C	105°C	±2 gauss	0.08 mgauss/LSB
			±4 gauss	0.16 mgauss/LSB
			±8 gauss	0.32 mgauss/LSB
			±12 gauss	0.48 mgauss/LSB
LSM303DLH CTR	-40°C - +85°C	125°C	±1.9 gauss	0.91 mgauss/LSB
			±2.5 gauss	1.17 mgauss/LSB
			±4.0 gauss	1.49 mgauss/LSB
			±4.7 gauss	2.22 mgauss/LSB
			±5.6 gauss	3.03 mgauss/LSB
			±8.1 gauss	4.35 mgauss/LSB

Table 4: Magnetometer Sensor Comparison

4.4 Global Positioning System (GPS) Research

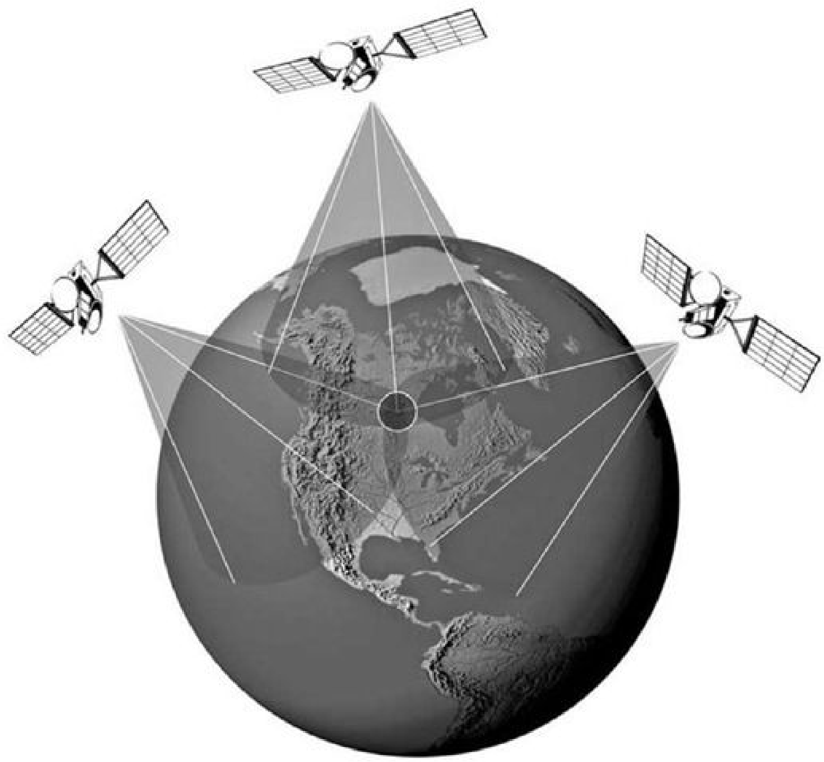


Figure 16: Global positioning system (Permission Pending) [64]

Global Positioning Systems is a United States government-based system that was originally created for military use by the Department for Defense (DoD) for satellite navigation. The modern system became fully operational in 1993 [19]. The system is constructed with at least 24 satellites at Medium Earth Orbit (MEO) at about 20,200 km (12,550 mi) above the Earth. The satellites are put in a total of 6 orbital planes, each are inclined 55° above the equator, with each satellite exactly 60° from the satellite in front of it and behind it on its orbital plane. Each of the satellites orbit the Earth once every 24 hours. The system is setup such that there are always satellites above every position on the globe in a way that the position can be determined from the satellites. [20] for proper communication a minimum of three satellites are needed for GPS triangulation shown above however it has been found that a fourth is typically needed for minor correction and accuracy.

The satellites are controlled by multiple land-based centers which ensure the satellites are in the right orbit, and functioning properly. Onboard the satellite, there are precise time circuits, called atomic clocks, which are necessary to determining the positioning of the user. This is necessary because there is actually a time differentiation between the clocks on the satellites and the time on Earth. This is because of the General and Special Theory of

Relativity. These theories dictate since the gravity exerted on the satellites is less than that on the surface, the circuitry will appear to run faster than the same circuitry on the surface. The satellites send their position and time to the receiver on the ground. The signals are sent at the speed of light. Thus, when it gets to the receiver, the timestamp sent by the satellite and the actual time will be different. From this, the distance to the satellite can be determined. There needs to be three satellites to triangulate the position of the receiver in an two dimensional way, such as latitude and longitude. However, the satellite systems are set up such that there are always 4 satellites in line of sight of every position on the planet, this is called trilateration. With these four satellites, the receiver can determine the latitude, longitude, and altitude. [21]

Each satellite emits three basic types of data. They are constantly transmitting at least 2 low-power signals which include pseudorandom code, or the satellite's identification. It also transmits what's called ephemeris data which has the satellite's position as well as the time and date that's onboard the satellite. To help the receiver, the satellite also transmits almanac data which contains where each satellite's orbital location at any time. GPS receivers are constructed of an antenna, and a chipset-based interface. The interface receives transmission signals from the GPS satellites through the antenna. These signals are then interpreted to determine the time it took to transmit the signal to receive the receiver. With this data, after a few iterations of the data being transmitted, the interface is able to determine the velocity and heading. [22]

4.4.1 GPS Specifications and Selection

Important characteristics for GPS modules for this application is acquisition sensitivity, or the strength level of the signal from the GPS satellites necessary in order to locate the module. Since the GPS module has to work in all areas a vehicle might be parked, the sensitivity has to be such that it can find the position of the vehicle inside of a parking garage, as well as in areas with tall buildings or trees that would affect the signal's strength. In the same area, the module's time to get its first fix is also important, a reasonable metric for comparing this is by means of comparing the number of channels on the module. The more channels, the possibility of lower fix times increases. The absolute minimum applicable number of channels is 12 to 14 channels [21, which would allow tracking but would take a relatively long time to lock.

With these comparisons in mind, a possible GPS module is the Maestro A2200-A, who has 48 channels, a time to first fix in a cold start being 35 seconds. It's acquisition sensitivity is on the higher spectrum of the modules that showed up during the search, with -163 dBm for tracking. Some other modules have as low as -143 dBm sensitivity for tracking. For cold start acquisition, the signal sensitivity is reduced to -148 dBm. Meaning the signal has to be stronger for it to be considered an acceptable level to track accurately. The warm start and cold start time to first fix is specified as being less than 35 seconds for each, with a hot start being less than one second. This module also passes the operating temperature test, with it's operating range being between -40°C to 85°C, which, again, is higher than the maximum temperature with a 5% error margin. The physical size of the module is 14 mm x 10.2 mm x 2.5 mm.

An alternative option is the Antenova M2M RF module, which has a smaller footprint of 9mm x 9mm x 1.8 mm. The cold acquisition sensitivity is -148 dBm. After the first fix, when it's "hot", the sensitivity for acquisition is -163 dBm, with a tracking sensitivity of -165 dBm. This is directly comparable to the Maestro A2200-A, except the Antenova M2M actually outperforms in the sensitivity department on hot acquisition and tracking. As well, the Antenova M2M has a decisively faster hot time to first fix, with the cold start being similar with less than 35 seconds, but the warm start is less than 25 seconds, and the hot start is less than 1 second, same as the Maestro A2200-A. As such, the channel structure of the Antenova M2M is different than the Maestro A2200-A in that it isn't one set number of channels, rather the Antenova M2M has 66 acquisition channels, and 22 tracking channels, versus the 48 channels of the A2200-A.

4.5 Wireless-Fidelity (Wi-Fi) Communication Research

As there will be a cloud-storage component of this system where the storage is located at a remote location to the vehicle or the owner's home, thus internet access is necessary. Wi-Fi communication is one part of this connection, as the base option. The concept being that when the vehicle is parked at your home, it will connect to the internet and upload all of the data that needs to be put on the cloud. The standard for Wi-Fi communication is noted as 802.11, which is a reference to the Institute of Electrical and Electronics Engineers (IEEE) standard 802.11, which refers to a set of media access control (MAC) and physical layer (PHY) specifications which allows the implementation of wireless local area networks. [20] There are multiple different sub-standards such as 802.11 a, b, g, etc. which refer to different modulation standards. The wireless module must be capable of communicating utilizing the IEEE standard as well as being capable to host the wireless network hotspot. The wireless hotspot will produce a network capable of communication between multiple devices while implementing standard WPA2 security as discussed in the security section of this paper. The network needs to be capable of supporting and routing traffic between a minimum of two devices, preferably more to allow for numerous users per device at a singular point in time. Due to the high power consumption utilized by wireless devices, it will be required for the wireless chip to have power consumption minimized as best as possible; this is critical as the device needs to be powered on for long periods of time to be efficiently utilized as a security device.

Wi-Fi communication works by means of transmitting data over one of two specific frequencies. Those frequencies are 2.4 gigahertz (GHz), and 5 GHz. The specific frequency ranges for the 2.4 GHz bracket that are utilized are 2.412 GHz to 2.472 GHz. Wi-Fi routers have specific channels which allow higher transfer rates due to low air traffic, since all of the data is ideally being transmitted over the range of channels. The less data per channel, the more efficient the data transmission is. Wi-Fi routers that are in the 2.4 GHz range have 12 different channels, while the 5 GHz routers have about 30 channels. However, the amount of channels varies by country. [53]

There are numerous methods for access point integration amongst wireless module chips. One such methodology enables non routing devices into virtual routers through the use of software, this method is named software enabled access point. This requires implementation at the software level and thus is requires high level abstraction for utilization. Most devices implementing SoftAP are incapable of being a client as well as producing a WLAN, they require the device to receive their internet communications through other means. In this case that may be achieved through the cellular communications module. Soft Access point remains the most widely used integration for ad-hoc integration in non-routing devices, utilized in popular embedded controllers such as the ESP82666.

Another method for performing wireless communication between devices is the implementation of Wi-Fi direct. Wifi direct enables devices to connect easily with each other through a singular channel without the implementation of a wireless access point; This is described as a single radio hop communication. The methodology can be equated to bluetooth communications where a system for pairing must be implemented.

4.5.1 Wireless-Fidelity Communication Selection

As such, standards implementations do not need to be taken into consideration. Multiple companies produce system on chips (SoC) which require minimal external components to function and provide internet connection. Some of these modules even have an integrated antenna built in. For instance, the Microchip ATWINC15x0-MR210xB is an IEEE 802.11 b/g/n module. This unit is an all-in-one unit with an integrated antenna, crystal, and chipset. It's maximum data rate is 72.2 Mb/s. For communication, the receiving signal strength sensitivity is important, especially in the environment of a car, and at potential distances from the router source that would be subject to. As such, the maximum signal sensitivity is -95 dBm, this is for 802.11b modulation at 1 Mbps (mega-bit per second). To achieve the maximum data transfer rate, the signal's strength must be -70.5 dBm or greater, this is under the 802.11n modulation range. Device size remains approximately 15 mm x 22 mm rounded up to provide minor padding for the device. The operating temperature range of this chip is within the necessary range, with the range being -40°C to 85°C. The interface for this unit involves serial peripheral interface (SPI) and universal asynchronous receiver-transmitter (UART). Support for Wi-fi direct and Soft access point are both available with implementation of all IEEE security standards such as WPA2. As well as fast boot features to enable to the device to reduce the time to live, which provides huge benefits for potential power saving by allowing the network to go done during non crucial periods.

An alternative choice is the Silicon Labs WGM110 Wizard Gecko, which also has a built in integrated antenna. Much like the ATWINC150x-MR210xB, it is set up to modulate by means of IEEE 802.11 b/g/n. The maximum data transfer is also 72.2 Mb/s. However, the Wizard Gecko has a maximum sensitivity rating of -98 dBm, which means it's more capable of transmitting at farther ranges, or under more harsh circumstances, when in comparison to the ATWINC150x-MR210xB. The interface capability of the Wizard Gecko includes SPI, UART, in addition to USB, and Inter-Integrated Circuit (I2C). Thus, the Wizard Gecko is capable of a more varied interfacing environment. Wireless for the device implements all required features for the product such as SoftAP as well as station mode (STA). Wireless security features are already implemented on the communication methods allowing for communication over WPA2 as required by our security guidelines. Device size similar to the ATWINC15x0-MR210xB, at 14.4 x 21.00 mm thus it is a slightly smaller profile than the ATWIN module. The operating temperature range is also from 40°C to 85°C.

Product Name	IEEE 802.11 Modulation Channels	Maximum Transfer Speed	Maximum Sensitivity	Interface Communication Protocol
Microchip ATWINC15x0-MR210xB	b/g/n	72.2 Mbps	-95 dBm	SPI & UART
Silicon Labs WGM110 Wizard Gecko	b/g/n	72.2 Mbps	-98 dBm	SPI, UART, & I2C
Texas Instruments CC3120MODR NMMOBR	b/g/n	72.2 Mbps	-95 dBm	SPI, UART, & I2C

Table 5: Wireless Chip Comparisons

4.6 Cellular Research

Code Division Multiple Access (CDMA) is a way of multiplexing numerous signals within a single transmission channel. This process of delving up the channel allows maximum use of the available bandwidth within the communication frequency. This is mainly used in cellular phone communication. By multiplexing the signals this allows the signals to not distort or cause interference for other signals in the channel. This process takes more processing power than GSM, and focuses on the use of what's called pseudo-noise (pn) codes to decode a combined message into its individual message. The pn code used to decode the signal is hardwired into the device. By using these pn codes many messages can be retrieved out of one massive message. The frequency used is in the ultra-high-frequency (UHF) range, which consists of frequencies from 800 MHz up to 1.9 GHz. Nominally, CDMA is 1.23 MHz wide, in which all mobile data transmission occurs in. Currently, the most commonly used CDMA protocol is the third generation, or 3G, and fourth generation, or 4G. [40] However, there is currently a fifth generation (5G) under works. This generation might be implemented in this system, if possible. A slight disadvantage of using CDMA is channel pollution or simply put to many users trying to access the the communication network. However, it is believed that this problem is highly unlikely unless due to an urgent widespread crisis arising. Another problem with CDMA is the lack of internationality. This means that international support of CDMA has been lacking, but is currently being phased out of countries outside the United States. Sprint stopped covering roaming CDMA users in countries outside the US in 2016. Understanding these key facts CDMA has been chosen for boards that function within the united states only.

Global System for Mobile (GSM) communication is another mobile telephone communication protocol, which is more common in Europe but is supported through a global marketplace unlike CDMA. It's a variation of Time Division Multiple Access (TDMA). GSM converts all data into digital format, then sends it down a channel alongside two other data streams. The purpose of sending the data through time division is that all the data gets sent essentially in a line, but each receiver knows what time to take each message from the line allowing multiple inputs to be sent as long as the time is known. The frequency that GSM operates in is very similar to the Ultra-High Frequency (UHF) range that CDMA utilizes, however GSM's operates typically within two specific frequency bands: Either 900 MHz, or 1800 MHz. [41] GSM requires a SIM card in order to connect to the correct network, they are utilized as an onboard memory device to provide the data plan, contact information and subscriber identity. This of course becomes an added cost to the production of a device implementing GSM based technology, but is essentially the only realizable choice for the SSDC use outside the United States.

Long Term Evolution (LTE) bases itself off of GSM. The protocol is a data only protocol, not allowing for voice; which in the case of this application is appropriate. The utilization of a SIM card is required in order for the device to know which networks it may communicate with. The protocol differs in implementation from GSM as opposed to time division multiple access the protocol utilizes frequency switching or orthogonal frequency division multiplexing (OFDM).

4.6.1 CDMA Module Selection

Sierra Wireless offers a product called MC7455, which is a Long-Term Evolution (LTE) module that supports the latest generations of CDMA communication, those generations being third generation (3G) and fourth generation (4G). The rated maximum uplink speed is 50 Mbps, and a rated maximum downlink speed of 300 Mbps. The MC7455 is certified with multiple carriers, such as AT&T, Verizon, Sprint, Vodafone and others that could be utilized in North America. There is driver support for Android and Linux, thus could be run off of any processor that would be utilized for this project. Since temperature range is important for this application, it's important to note that the extended operating temperature range of the MC7455 is from -40°C to +85°C, which is finely suited to the environments in a vehicle. An added bonus to this module is that there is a GPS module located on the chipset. The CDMA chip will have the most reliable coverage throughout the United States but it will have no coverage anywhere else in the world. However, these features come at a price which exceeds that of other GSM options.

4.6.2 GSM Module Selection

The company Adafruit offers a breakout board with all of the modules necessary for GSM cellular connection. This board, known as the Adafruit FONA (product ID 1946) has quad-band connection capabilities with the ranges 850, 900, 1800, and 1900 MHz which can connect to any global GSM network with any second generation (2G) SIM card. Onboard the breakout board is a uFL connector to attach an external antenna. The interface utilizes auto baud detection, to ensure the proper baud rate is used when attempting to transmit data, voice, or text. However, the application would only utilize the data connection. Onboard this breakout board is a LiPoly battery charger circuit. There are also voltage level shifting elements that allow the board to run with any voltage from 2.8v to 5V logic levels. Then, of course, is a standard SIM card slot on the reverse of the board to allow the system to have all of the connection information and data plan necessary. The processing necessary just requires any processor that utilizes 3 to 5 volts and can communicate via universal asynchronous receiver-transmitter (UART) protocols. The subsystem on this breakout board also contains a GPS module, which has a -165 dBm tracking sensitivity.

Adafruit also offers a product called SIM808, which is nearly identical to the FONA in that it's an all-in-one unit that has quad-band connection capability. The same 850, 900, 1800, and 1900 MHz range as the FONA. The SIM808 similarly works with any 2G SIM card, and has a fully integrated MT3336 GPS chipset with -165 dBm tracking sensitivity, much like the FONA. In many ways, it is identical to the FONA except in it's form. The FONA has a SIM808 at it's core, with different connections and auxiliary circuitry to allow it to be a breakout board. The SIM808 is bare-bones and requires any external circuitry to be added, such as an antenna connection, SIM card holder, battery charger and battery port, headphone connection, and other circuitry that might be superfluous to the application.

The development boards available for use are mostly 2G models. The cell chipset needs to have the capability of 4G using the CDMA technology for video data transfer. The GSM technology will be used for international purposes. The CDMA technology is usually cheaper. The GSM technology is more expensive but can adapt globally to all cell carriers with the correct frequency tuning. The device will need to compress and send video data to the cloud and to the user's phone. The device will use a 4G chip. The 4G chip will be selected based on how readily available the chips are, the chip samples, and datasheets provided. A development board for the 4G cellular chip may have to be constructed using Eagle in order to complete the breadboard prototype design of the PCB. The development board may also be purchased from the chip manufacturer. These development boards range from $200-$600 depending on brand and capability.

Product Name	Communication Standard	Generation Support	Frequency Range	Interface Communication Protocol	GPS
Adafruit FONA	GSM	2G	850, 900, 1800, 1900 MHz	UART	Yes
Adafruit SIM808	GSM	2G	850, 900, 1800, 1900 MHz	UART	Yes
Sierra Wireless MC7455	CDMA	3G & 4G	LTE	Linux & Android	Yes

Table 6: Cellular Chip Comparison

4.7 Camera Research

Digital video and photography is done in a novel way, in comparison to film video and photography. In digital photography, rather than a strip of light-sensitive film, a solid-state module is used to capture the light required for a digital image. The most basic form of digital photography is a light sensor, which will change the signal based on the intensity of light. High resolution digital photography is very similar to that process. However, for high resolution photography, there are a large array of various light sensors arranged onto a wafer. This is called an image sensor. During the manufacturing process of the sensor, wells are created in a silicon wafer which house light sensitive elements, these wells with light sensitive parts are called pixels. Image sensors can range in having only a few pixels on the sensor, such as a 400 pixel by 400 pixel low-resolution image sensor, upwards to 16 or more megapixels (16,000,000 or more).

The output of this sensor is continuous, as the image sensor is an analog device. As such, in order for the sensor to act properly with a digital processor and digital circuits, it must be converted and handled in such a way to convert the continuous analog output to a form that can be understood by the processor. This is done by dedicating each pixel to a unique number so the processor can articulate the image in a meaningful way. Since each pixel can only determine the brightness of a color, filters are placed over each pixel so that it only reacts to a specific range of colors. These colors are red, green, and blue. A colorless sensor can also exist without these filters, however. However, for this application a color sensor is to be used. Because there are now three colored pixels, the processor needs to assemble the pixels in a way that would be actually representative of the real-world view. This is done by a process known as demosaicing, where the processor combines the three pixels for a given area, and collects all of the different pixels into a single image, where a pixel in the final image is actually an amalgam of the results from the red pixel, the green pixel, and the blue pixel of a given area. [42] Thus, an image is made by the reflection of light off of an object or person with unique light wells that produces a pixel representation of that image. The most basic image is the output of a simple light sensor, which could be representative of a single grayscale pixel of the image. The more pixels that are able to acquire reflected light, the better the representation of the image is. This is called resolution. Resolution is most commonly given in the form of width of pixels then the height of pixels. Such as, "1920x1080" refers to a resolution that is 1,920 pixels wide, and 1080 pixels high.

The light that interacts with the camera sensor can be focused using a lens. Without a lens, the light that's incident with the visual sensor is too plentiful for the sensor to work properly. As such, a photograph or video taken without a lens is out of focus and otherwise unusable. This is because what's known as the focal length is set at infinity. This causes the pictures to be unfocused. Also, the aperture is set to infinity, causing too much light to hit the sensor. This causes the image to lose the contrast in the image, leading it to become washed out. Thus, a lens must be fitted to the digital image sensor to allow the sensor to function as necessary. [43]

In regards to still images, the digital image sensor typically reacts with the incident light over a period of time. This period of time is called shutter speed. Some digital image sensors are able to achieve speeds up to 1/8000th of a second and faster in high-end digital single-lens reflex cameras (DSLR). This effective shutter speed will determine how blurry a moving object or person is when taking both a picture and a video. However, a higher shutter speed is also associated with having better low-light sensitivity. This is because the light well that's associated with collecting photons for each pixel is able to collect more light for each image. This means that the light reflecting off a moving object or person might interact with the specific light sensor more than once for a given image, or frame. [50]

Video, for all intents and purposes, is a stream of contiguous images that are shown in such a way that there is a representation of what was in front of the image sensor. The number of images that can be used can vary greatly. It can be as extreme as one image every 5 seconds or more, down to over 120 pictures every second. In video, the name of each image is known as a frame. So, the frame rate is typically in the form of frames per second (fps). The higher the frames per second, the smoother the video appears. [51] The average human The average human mainly perceives movement in the range of 7 and 13 fps. However, higher frame rates increase the sensitivity to movement, but at an exponentially lower rate. [52] It appears that 30 frames per second is a good baseline for clear videos. However, 60 frames per second are objectively better, and would result in a smoother perceived image.

4.7.1 Camera Sensor Research

A proper camera sensor must be adequately chosen such that there's a maximization and balance between performance and resource allocation. However, resolution is necessary to properly identify people, things, or vehicles that would be of importance. There are two main forms of camera sensors. One is named charged couple device (CCD), and the other is called complementary metal oxide semiconductor (CMOS). Both types of sensors work the same way, by converting light energy to a signal. For CCD, the voltage created by the light incident with the sensor is channeled out through a small number of output channels, and sent to an external controller or processing circuit as an analog signal. Since this system is basically a uniform input-output system, the entire area can be devoted for the light hitting the pixel causing a general uniformity to the image, increasing the image's quality. The analog output acts as a bandwidth bottleneck so processing speed is limited.

The CMOS sensors work in a different way in that they don't output an analog signal. In fact, the CMOS sensors function by means of processing at a pixel level. Each pixel has integrated components such as charge-to-voltage converters, amplifiers, noise correction circuitry, and digitizing circuitry. Thus, the sensor has a digital output, versus the CCD's analog output. The benefit of this is that it allows for a massively parallel system, which utilizes a large amount of bandwidth. However, the disadvantage of this CMOS system is that a much smaller area of each pixel can be dedicated to light capture. Since there is less physical area where light can interact with the sensor, the uniformity of the image, in terms of quality, is reduced somewhat greatly. [44]

4.7.2 Camera Lens Research

The lens can set the focal length, aperture, and effectively the range of view. The shorter the focal length, the wider the view is. This would be beneficial to the application at hand as with the increase in number of cameras would increase the burden on not only the visual subsystem, but all other supporting subsystems. Since the goal is to use 2 cameras, a wide angle lens must be used to get the most range of view as possible. The ideal field of view (FOV) is 180°. However, a true 180° lens is technically impossible. There are quite a few CMOS cameras that are fitted with wide angle lenses, such as 160°, and 170°. However, some lenses are rated for an angle that the lens cannot reasonable produce. [45]

4.7.3 Camera Sensor Selection

The goal of camera selection should be a resolution of no less than 786 pixels by 494 pixels. Many CMOS camera sensors are labeled using security camera nomenclature. The security cameras are described by something called TV lines (TVL). TVL naming methods equate to half of the number of black vertical lines, and half white vertical lines. An example of this is an instance of 400 TVL, this equates to 200 alternating dark vertical lines and 200 light vertical lines. The following table, which was extracted from a website, shows the comparison between TVL and NTSC resolutions. [46]

<table>
<tr><td>Device</td><td>TVL/Pixel</td><td>Effective Pixel NTSC</td><td>Effective Pixel PAL</td><td>Total NTSC</td><td>Total PAL</td></tr>
<tr><td rowspan="3">Analog SONYCCD</td><td>480TVL</td><td>510H*492V</td><td>500H*582V</td><td>~0.25 megapixel</td><td>~0.29 megapixel</td></tr>
<tr><td>600TVL</td><td>786H*494V</td><td>752H*582V</td><td>~0.38 megapixel</td><td>~0.43 megapixel</td></tr>
<tr><td>700TVL</td><td>976H*494V</td><td>967H*582V</td><td>~0.48 megapixel</td><td>~0.56 megapixel</td></tr>
<tr><td>Analog SONY CMOS</td><td>1000TVL</td><td colspan="2">1280H*720V</td><td colspan="2">~0.92 megapixel</td></tr>
</table>

Table 7: TVL to NTSC Pixel Conversion Chart (Permission Pending) [46]

From the above table, it is clear the TVL-minimum for this application is the 600TVL. Due to it meeting the numerous restraints and concerns required for the quality of our device. The issue being the production value of the the device and closed source mindset behind the suppliers technologies.

Product Name	Resolution	Lens	Operating Temperature Range
Wide Angle Mini FPV - HobbyKing SKU: 640000002-0	700TVL	160° Horizontal, 127° Diagonal, 2.6 mm	-20°C - +70°C
KrazePony Wide Angle FPV for QAV240-Multicopter (AZ)	1000TVL	120° 3.6 mm	-20°C - +60°C
VIDEOTORG Mini FPV for Quadcopter QAV250 (AZ)	1000TVL	120° 2.8 mm	-10°C - +50°C
CrazePony FPV Camera 1.2G (AZ)	1000TVL	170° 2.8 mm	-10°C - +50°C
OmniVision OVP0921-B44G (Digikey)	1280x720 NTSC	N/A	+10°C - +70°C

Table 8: Camera Lens Comparison

4.8 Storage

The storage of the device will be in the form of a micro SD card. Connected to the PCB board via a micro SD push port. Considering that the SSDC will be recording at a constant 1080p there has to be enough space to hold enough footage until the SSDC reenters either wifi or Cellular range. With this in consideration an SD storage card of 256GB was chosen to meet the storage needs of the SSDC. The size of 256GB for the SD card was chosen because this value equates to around 53 hours of 1080p recording time for a single camera. With two cameras this SD card will last for approximately one full day of recording, and the average user is not expected to drive continuously to fill up these hours. Also in correspondence with the law an individual is not allowed to drive more than 10 hours in a single instance. Also this amount of time for recording was chosen so that the user would not have to worry about running out of recording space on the device.

The connection of the micro SD card to board will be established through the use of a micro SD card connector. To connect these two to allow for communication the connector datasheet has to be pulled up then the data pins on the layout have to be connected to the Micro controller. For the voltage inputs SD cards and ports require a very precise voltage current, so a voltage divider is not a recommended choice or you could corrupt the data or even damage the card. To achieve a very stable input voltage a level shifter for a stable input vcc. Following the other pins of the sd connector of ground and clk the SD card will be connected to the micro controller. Also it is recommended to check the sizes of allowance for both the SD card connector and the actual SD card so that it is guaranteed that the two are compatible.

4.9 Power Management Research

The main power source for the components is going to be the car's battery, which is nominally 12 volts. However, as the car sits, starts, and runs, the voltage on the battery will change. The principle issue is that there will be a few different voltages that need to be held constant in order for all of the various components to work harmoniously. A car's battery must be above 12.4 voltage to be able to operate the car and turn the engine on. While the vehicle is operating, the charging voltage, or the voltage that's present on the connection posts of the battery is nominally in the range of 14.2 volts to 14.5 volts [23]. Voltage ranges applicable for this system includes 5 volts, 3.6 volts, and 3.3 volts. There are various ways in which these voltages can be achieved.

4.9.1 Methodologies of Power Supply

One way to reach these voltages are by using basic voltage regulators, such as the Thomson Microelectronics TEA7605, which is a 5 volt regulator. The benefits of this method are that it's simple to produce, and the output is within a range of ±4%, which means it has a drift range of 0.4 volts from the median. This would put the output voltage within the range of acceptable levels for almost every module that would be used. However, the method in which this regulator works is by turning the excess voltage into heat energy. Which would heat up the entire system that would be inside of the case with this regulator. Further, this method is very wasteful, and thus would lower the max idle time the unit could run with the vehicle off.

An alternative method to this is a step-down converter, or a buck converter. Buck converters are DC-to-DC power converters which step down a higher voltage to a lower one. One side effect of this is to increase the total current of the system. Buck converters work by means of switching a circuit that includes an inductor, capacitor, and diodes, on and off. The interaction with these components creates a voltage step-down and current step-up based on the various values of each component. The downside of this is the possibility that the energy which is stored in the inductor could affect the communications of other on-board modules with its expanding and contracting magnetic field. [24]

4.9.2 Power Supply Part Selection

The SSDC will be supplied power from the battery of the vehicle in which it resides. This will require having someone properly install the SSDC or having the proper knowledge to do it alone. Since the power comes from the car battery voltage regulator will be used to adjust the voltage to a usable level.

4.10 Microcontroller

Microcontroller is a single chip microcomputer made through VLSI fabrication. A microcontroller also called an embedded controller because the microcontroller and its support circuits are often built into, or embedded in, the devices they control. A microcontroller is available in different word lengths like microprocessors (4 bit, 8 bit, 16 bit, 32 bit, 64 bit and 128 bit microcontrollers are available today). [61] A microcontroller functions as a computer as it has several things in common:

- All computers have a CPU (central processing unit) that executes programs. If a user is sitting at a desktop computer right now, the CPU in that machine is executing a program that implements the Web browser that is displaying this page. [59]
- The CPU loads the program from somewhere. On a user's desktop machine, the browser program is loaded from the hard disk. [59]
- The computer has some RAM(random-access memory) where it can store "variables." [59]
- And the computer has some input and output devices so it can talk to users. On a user's desktop machine, the keyboard and mouse are input devices and the monitor and printer are output devices. A hard disk is an I/O device -- it handles both input and output. [59]

Microcontrollers are embedded into devices to control the features and functions of products. Most of these products are consumer products, which is why microcontrollers they are popular in usage for electronic devices in modern society. Devices that are used to measure, store, control, calculate, or display any information usually contain a microcontroller. The largest single use for microcontrollers is in automobile industry (microcontrollers widely used for controlling engines and power controls in automobiles). Consumers can also find microcontrollers inside keyboards, mouses, modems, printers, and other peripherals. In test equipments, microcontrollers make it easy to add features such as the ability to store measurements, to create and store user routines, and to display messages and waveforms. Consumer products that use microcontrollers include digital camcorders, optical players, LCD/LED display units, etc. [61]

In comparison to a desktop computer, which is a "general purpose computer" that can run thousands of programs, the microcontrollers are "special purpose computers." [59] These characteristics define a microcontroller and even a computer as a "special purpose computer":

- Microcontrollers are "embedded" inside some other device (often a consumer product) so that they can control the features or actions of the product. Another name for a microcontroller, therefore, is "embedded controller." [59] For the case of this project, the microcontroller will be used in an embedded device as a part of the team's SSDC, a security camera that will be used to detect and record car theft and car damage. This product also acts as a consumer product as appropriate for this project.

- Microcontrollers are dedicated to one task and run one specific program. The program is stored in ROM (read-only memory) and generally does not change. [59] ROM is generally nonvolatile memory, which means that the data is retained and be retrieved in the storage when there is a break in the voltage supply or the power is turned off compared to RAM, which is generally volatile memory, which requires voltage and a power supply to store and retain data.

  When designing the SSDC device around the microcontroller's ROM, it should only contain programs and data that do not generally change. However, while the SSDC design does contain a lot of components, the ROM should be kept at a minimum as some ROM will not be needed unless using a thousand parts for the design, and can be potentially useless. A good amount of RAM would be needed for the SSDC device has a lot of data from multiple "variables" will be collected and recorded from the SSDC device to detect car theft and car damage.

- Microcontrollers are often low-power devices. A desktop computer is almost always plugged into a wall socket and might consume 50 watts of electricity. A battery-operated microcontroller might consume 50 milliwatts. [59]

  This is essential as the SSDC device will require multiple components with a minimum amount of power used as possible as the device will be powered by the car's power supply. It would be inconvenient for the user to have the device use the car's power while the device is active and the car is not and waste the car's power, so the power consumption for the device should be kept at a minimum.

- A microcontroller has a dedicated input device and often (but not always) has a small LED or LCD display for output. A microcontroller also takes input from the device it is controlling and controls the device by sending signals to different components in the device.

  For example, the microcontroller inside a TV takes input from the remote control and displays output on the TV screen. The controller controls the channel selector, the speaker system and certain adjustments on the picture tube electronics such as tint and brightness. The engine controller in a car takes input from sensors such as the oxygen and knock sensors and controls things like fuel mix and spark plug timing. A microwave oven controller takes input from a keypad, displays output on an LCD display and controls a relay that turns the microwave generator on and off. [59]

The SSDC device will take inputs from the mobile application by the user to the user's device and accelerometer, gyrometer, and magnetometer data to detect car theft and car damage, while the device will output notifications, recorded footage, and images, of the instance of car theft and car damage.

- A microcontroller is often small and low cost. The components are chosen to minimize size and to be as inexpensive as possible. [59] The design of the SSDC device will generally choose the essential components that will meet the requirement specifications while also being at a minimum low cost.

  This is to prevent the device from being too costly as there are multiple components needed for the SSDC device. Using a microcontroller is also beneficial for its size as the SSDC device will have to be small enough to meet the project's standards and requirements as the device will be place behind a rear-view mirror.

- A microcontroller is often, but not always, ruggedized in some way. The microcontroller controlling a car's engine, for example, has to work in temperature extremes that a normal computer generally cannot handle. A car's microcontroller in Alaska has to work fine in -30 degrees Fahrenheit (-34 degrees Celsius) weather, while the same microcontroller in Nevada might be operating at 120 degrees Fahrenheit (49 degrees Celsius). When you add the heat naturally generated by the engine, the temperature can go as high as 150 or 180 degrees Fahrenheit (65-80 degrees Celsius) in the engine compartment. On the other hand, a microcontroller embedded inside a VCR hasn't been ruggedized at all. [59]

  This is relevant to the SSDC device as the microcontroller will need to be functional and operate to meet the requirements and be able to record data during extreme temperatures. There will need to be selection of a proper microcontroller to meet the expected temperatures inside a car in order to be functional.

4.10.1 Microcontroller Components

The microcontroller contains multiple components within its structure: Central processing unit (CPU), Random Access Memory (RAM), Read Only Memory (ROM), Input/output ports, timers and counters, interrupts controls, etc. The microcontroller consists of features that are required for a computing system and functions just similarly to a computer, excluding any external digital parts inside it. A user is able to program the pins on the microcontroller chip, which will be used in the SSDC device's design as inputs and outputs to collect data and create responses. The microcontroller has many bit handling instructions that can be easily understood by programmers, is capable of handling boolean functions, has high speed and performance, has an on-chip ROM structure inside of it to provide better firmware security, and is easy to design at a low price and small size. [61]

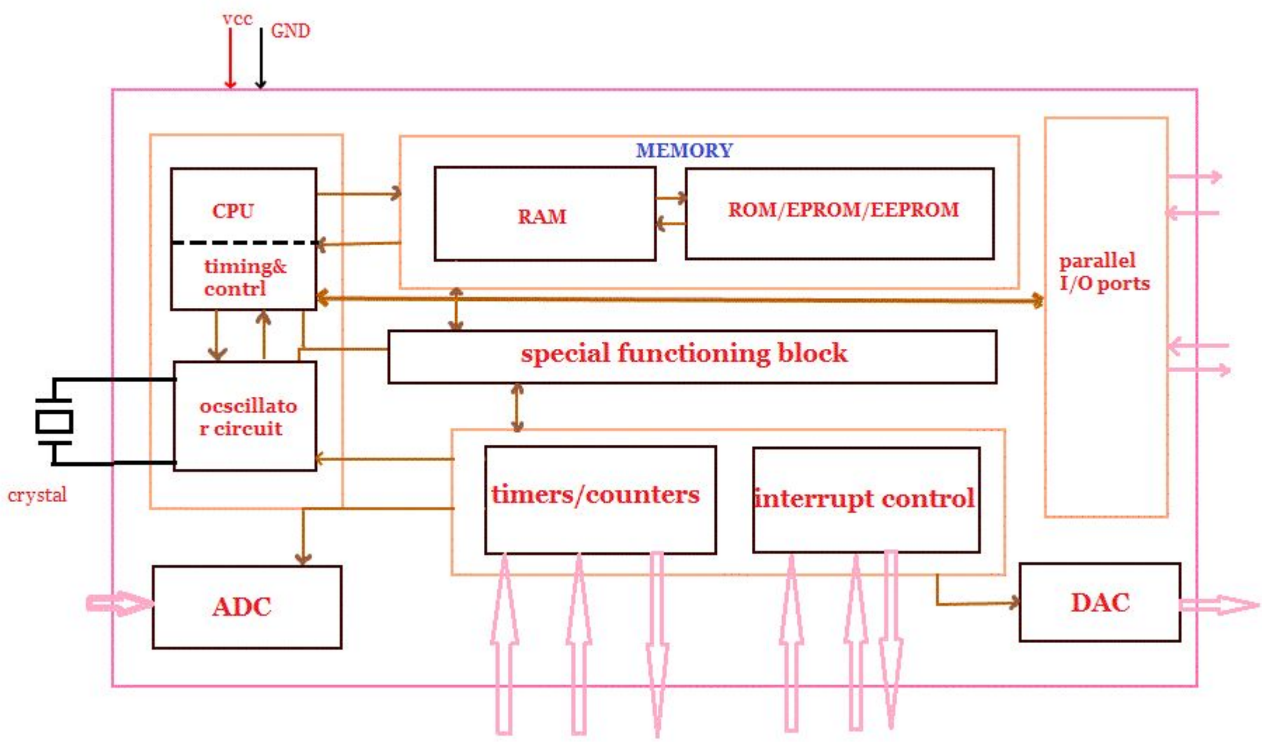


Figure 17: Microcontroller Structure and Components (Permission Pending) [61]

The figure above shows the structure and a diagram of the microcontroller that includes these components:

- CPU (Central Processing Unit) - is the brain of a microcontroller. CPU is responsible for fetching the instruction, decodes it, then finally executed. This component is also known as the processor, hence why it is where the calculations and instructions take place. CPU connects every part of a microcontroller into a single system. The primary function of CPU is fetching and decoding instructions. Instruction fetched from program memory must be decoded by the CPU. [61]

  CPUs are included as an internal component in all computers, as well as microcontrollers, and microprocessors. There are two components of the CPU itself, which is the ALU (Arithmetic Logic Unit) and the CU (Control Unit). The ALU is responsible for performing any arithmetic and logical operations, while the CU extracts instructions from the memory and decodes and executes them, and also calls the ALU if necessary.

- Memory - The function of memory in a microcontroller is same as microprocessor. It is used to store data and program. A microcontroller usually has a certain amount of RAM and ROM (EEPROM, EPROM, etc.) or flash memories for storing program source codes. [61] There are different types of memory when using microcontrollers and in embedded systems:

    - RAM (Random Access Memory) - RAM is a type of computer memory that is accessed randomly, which means the memory is accessed without interacting with preceding bytes. RAM memory is volatile, which means that it is dependent on the power supply of the device to retain data and memory.

      The RAM family includes two important memory devices: static RAM (SRAM) and dynamic RAM (DRAM). The primary difference between them is the lifetime of the data they store. SRAM retains its contents as long as electrical power is applied to the chip. If the power is turned off or lost temporarily, its contents will be lost forever. DRAM, on the other hand, has an extremely short data lifetime-typically about four milliseconds. This is true even when power is applied constantly. Many embedded systems include both types: a small block of SRAM (a few kilobytes) along a critical data path and a much larger block of DRAM (perhaps even Megabytes) for everything else.[63]

      SRAM is used for the device's system cache and does not need its memory to be refreshed as it retains the data depending on the device's power supply and loses its data once the power supply is turned off or experience a break in power. SRAM devices offer extremely fast access times (approximately four times faster than DRAM) but are much more expensive to produce. Generally, SRAM is used only where access speed is extremely important.

      DRAM is used for main memory in computing devices, such as PCs and smartphones, and this memory needs to be constantly refreshed in order to retain data, hence why the data has an extremely short lifespan. The job of the DRAM controller is to periodically refresh the data stored in the DRAM. By refreshing the data before it expires, the contents of memory can be kept alive for as long as they are needed. A lower cost-per-byte makes DRAM attractive whenever large amounts of RAM are required. [63]

- ROM (Read Only Memory) - ROM is a type of computer memory that cannot be removed or changed from the device it is placed in and can only be read. Unlike RAM, ROM is nonvolatile, which means the data and memory is retained even when the power supply is turned off. Most PCs and personal mobile devices contain only a small amount of ROM to execute essential programs for booting the system and is common in calculators and peripheral devices. There are two types of ROM available: PROM and EPROM.

  One step up from the masked ROM is the PROM (programmable ROM), which is purchased in an unprogrammed state. If you were to look at the contents of an unprogrammed PROM, you would see that the data is made up entirely of 1's. The process of writing your data to the PROM involves a special piece of equipment called a device programmer. The device programmer writes data to the device one word at a time by applying an electrical charge to the input pins of the chip. Once a PROM has been programmed in this way, its contents can never be changed. If the code or data stored in the PROM must be changed, the current device must be discarded. As a result, PROMs are also known as one-time programmable (OTP) devices. [63]

  An EPROM (erasable-and-programmable ROM) is programmed in exactly the same manner as a PROM. However, EPROMs can be erased and reprogrammed repeatedly. To erase an EPROM, you simply expose the device to a strong source of ultraviolet light. (A window in the top of the device allows the light to reach the silicon.) By doing this, you essentially reset the entire chip to its initial--unprogrammed--state. Though more expensive than PROMs, their ability to be reprogrammed makes EPROMs an essential part of the software development and testing process. [63]

- Hybrid Memory - As memory technology has matured in recent years, the line between RAM and ROM has blurred. Now, several types of memory combine features of both. These devices do not belong to either group and can be collectively referred to as hybrid memory devices. Hybrid memories can be read and written as desired, like RAM, but maintain their contents without electrical power, just like ROM. Two of the hybrid devices, EEPROM and flash, are descendants of ROM devices. These are typically used to store code. The third hybrid, NVRAM, is a modified version of SRAM. NVRAM usually holds persistent data. [63]

  EEPROMs are electrically-erasable-and-programmable. Internally, they are similar to EPROMs, but the erase operation is accomplished electrically, rather than by exposure to ultraviolet light. Any byte within an EEPROM may be erased and rewritten. Once written, the new data will remain in the device forever--or at least until it is electrically erased. The primary tradeoff for this improved functionality is higher cost, though write cycles are also significantly longer than writes to a RAM. So you wouldn't want to use an EEPROM for your main system memory. [63]

Flash memory combines the best features of the memory devices described thus far. Flash memory devices are high density, low cost, nonvolatile, fast (to read, but not to write), and electrically reprogrammable. These advantages are overwhelming and, as a direct result, the use of flash memory has increased dramatically in embedded systems. From a software viewpoint, flash and EEPROM technologies are very similar. The major difference is that flash devices can only be erased one sector at a time, not byte-by-byte. Typical sector sizes are in the range 256 bytes to 16KB. Despite this disadvantage, flash is much more popular than EEPROM and is rapidly displacing many of the ROM devices as well. [63]

The third member of the hybrid memory class is NVRAM (non-volatile RAM). Non-volatile memory is also a characteristic of the ROM and hybrid memories discussed previously. However, an NVRAM is physically very different from those devices. An NVRAM is usually just an SRAM with a battery backup. When the power is turned on, the NVRAM operates just like any other SRAM. When the power is turned off, the NVRAM draws just enough power from the battery to retain its data. NVRAM is fairly common in embedded systems. However, it is expensive--even more expensive than SRAM, because of the battery--so its applications are typically limited to the storage of a few hundred bytes of system-critical information that can't be stored in any better way. [63]

- Parallel input/output ports - Parallel input/output ports are mainly used to drive/interface various devices such as LCD’S, LED’S, printers, memories, etc. to a microcontroller. [61]

- Serial ports - Serial ports provide various serial interfaces between microcontroller and other peripherals like parallel ports. [61]

- Timers/counters - This is the one of the useful function of a microcontroller. A microcontroller may have more than one timer and counters. The timers and counters provide all timing and counting functions inside the microcontroller. The major operations of this section are perform clock functions, modulations, pulse generations, frequency measuring, making oscillations, etc. This also can be used for counting external pulses. [61] Timers and counters will be used during recording and taking images during car theft and car damage during the instance. It could be used to record the time of the incident and take a number images in time intervals.

- Analog to Digital Converter (ADC) - ADC converters are used for converting the analog signal to digital form. The input signal in this converter should be in analog form (e.g. sensor output) and the output from this unit is in digital form. The digital output can be use for various digital applications (e.g. measurement devices). [61]

- Digital to Analog Converter (DAC) - DAC perform reversal operation of ADC conversion. DAC convert the digital signal into analog format. It usually used for controlling analog devices like DC motors, various drives, etc. [61]

- Interrupt control - The interrupt control used for providing interrupt (delay) for a working program .The interrupt may be external (activated by using interrupt pin) or internal (by using interrupt instruction during programming). [61]

  The SSDC device will constant detect the user's vehicle's motion from the accelerometer, gyrometer, and magnetometer. The data received from these components will constantly be monitored, until an instance of car theft or car damage is detected, which will trigger the device. Multiple interrupts and if conditions will be made to filter out any false positives and only detect a proper instance of car theft and car damage. These interrupts will also be used to send notifications, recorded footage, and images to the user's mobile application. However, the interrupts must be coded correctly to prevent polling in the case of nested interrupts or repeated execution of instructions in the interrupts with no breaks from the interrupts.

- Special functioning block - Some microcontrollers used only for some special applications (e.g. space systems and robotics) these controllers containing additional ports to perform such special operations. This considered as special functioning block. [61]

4.10.2 Microcontroller Advantages and Disadvantages

Advantages of Microcontrollers

- Flexibility - Microcontrollers are special types of processor chips that are very small and somewhat flexible, due to their programmable nature. [62] The microcontroller acts as a microcomputer without any of a computer's digital parts [61]

- Faster Speed of Execution - Since microcontrollers are fully integrated inside the processor, i.e., a “computer on a chip,” these devices operate at faster speeds to execute instructions compared to general purpose microprocessors. [62] Low time is required for performing operations. [61]

- Inexpensive - As microcontrollers are fully integrated onto one chip, these devices are cheap to manufacture. Usually, microcontrollers have much lower specifications than lower specifications than low-power consumer-grade general-purpose microprocessors, making them even easier to mass produce. [62] As the higher integration inside microcontroller reduce cost and size of the system. [61]

- Rigid - Once microcontrollers are programmed, typically they cannot be reprogrammed, if microcontrollers are controlled by Read-Only Memory (ROM) only rather than Random Access Memory (RAM). [62] ROM has the data retained even without the power supply as it is nonvolatile memory, but contains programs that cannot be changed.The additional RAM, ROM, and I/O ports can be easily interfaced [61]

- Labor Saving - Many tasks can be performed by microcontrollers repetitively and human efforts can be saved. The programmable nature of these devices also allows manufacturing robots to reproduce these motions very quickly and consistently, increasing productivity. [62] The usage of the microcontroller is simple and it is easy for troubleshooting and system maintaining. [61]

- Applications - Microcontrollers are widely used in modern electronics equipments, such as industrial and household applications which includes measuring physical quantities in pressure, force, velocity, acceleration, etc., measure metrics of circuits in voltage, current, phase angle, power factor, frequency, resistance power, energy, etc., robotics, biomedical instruments, peripheral controller in a PC, automobile applications, motor controls, household applications such as washing machines, light controls, cameras, TV, etc., and office equipments such as photocopying machines, telephones, fax machines, printers, security system, etc. [61]

Disadvantages of Microcontrollers

- Complex Architecture - Microcontrollers have more complex architecture than microprocessors. Therefore, understanding their functionality is quite difficult. [62]

- Development Time - Due to complexity to the circuit board, the development time of a microcontroller increases and cost increases. [62]

- Limitations - Microcontrollers can only perform limited number executed instructions simultaneously. Microcontrollers are also used mostly in small devices and cannot interface high power devices directly. [61]

4.10.3 Atmel Microcontrollers

Atmel microcontrollers is an example of a leading corporation and manufacturer in the development of microcontrollers. The microcontrollers provided features that are useful for the SSDC device's design and meet the purpose of the device. (Note: The use Atmel microcontrollers is not final, but will be used as a reference to meet the specification requirements for the microcontroller inside the SSDC device).

Today's mobile products continue to change the way people consume information, socialize, conduct business, and buy products. Meeting the needs of increasingly mobile consumers now requires solutions that offer:

- Support for intuitive touchscreen interfaces [60]
- Efficient power management [60]
- Fast response time for nimble operation [60]
- Highly integrated designs for small footprints and minimal bill-of-materials (BOM) costs [60]
- Secure hardware-based authentication of accessories [60]

(Note: That these issues will most likely not be met as the SSDC device being made is a student project as it only needs to meet the requirement specifications made. However, the right selection of components are needed to meet the requirements needed for the device.)

Atmel microcontrollers provide extensive mobility with touch, power, and security. The microcontroller electronics that the SSDC device is considered with Atmel are its cameras and GPS tracking.

- Cameras - Combine the best picture taking with exceptional speed and minimal power consumption. The broad family of Atmel ARM®-based microcontrollers integrate all the functions required to implement digital cameras on a single-chip.

  This includes capturing, processing, compressing, displaying, and storing images in Flash memory cards, as well as controlling camera functionality through the use of an integrated processor. In addition, the Atmel ATSHA204 CryptoAuthentication IC authentication chip family is the only battery authentication IC that uses a SHA-256 cryptographic engine and a 256-bit key to protect cameras from counterfeit accessories, such as battery packs. [60] The cameras are necessary as they are essential to recording the car theft and car damage. They also need to have clear images with minimal power consumption in the device to meet the requirements.

- GPS for Fleet Management, Asset-, Vehicle-, and Personal-Tracking - GPS-enabled tracking devices are gaining popularity for fleet management, vehicle-, and asset-tracking and as a security feature for the elderly and children.

  Vehicle trackers not only ensure productivity and visibility of a fleet of delivery vehicles, they can help mold a teen driver into being a responsible motorist. They can also assist in locating your car if it is stolen or you simply do not remember where you parked at the mall. For the elderly or people with special needs, a GPS-enabled tracking device can be the difference between life and death. A GPS tracker can alert a caregiver the instant a special needs patient wanders outside of their home, or help relatives locate someone who is lost. [60] The GPS tracker is used in cases of when the user cannot find their vehicle or in the case of car theft can track their stolen vehicle once they are notified of the incident. GPD for vehicle tracking will be beneficial for the user during the case of car theft.

The Atmel microcontrollers provides advantages of low power consumption, better signal;-to-noise ratio, single-chip touch solutions, rigorous security, etc.

- Lower Power Consumption - maXTouch devices feature extremely low current consumption, less than 1.8 mW in "touch-ready" state with startup time below 10 ms from idle. Atmel picoPower® technology provides power-saving modes to conserve power while offering abundant performance. [60] The power consumption from the microcontroller must be low as well as the other components in order to prevent excessive power consumption to the vehicle’s power supply.

- High-Security Hardware Authentication - Software-only security solutions are notoriously weak. Atmel provides low-cost, high-security hardware authentication solutions, including the ability to integrate security with Atmel AVR microcontrollers and ARM-based microcontrollers. Atmel CryptoAuthentication is the first authentication chip family using the SHA-256 hash algorithm, the latest U.S. government-recommended algorithm for superior algorithm security, to authenticate accessories, battery packs, or any replaceable item that contains a power source. [60] There needs to be security provided within the SSDC device to prevent harmful effects from other users onto the user’s vehicle and the SSDC device.

- Responsiveness - Response time is a critical success factor in the user experience. maXTouch touchscreen controllers are designed to support the most response-sensitive applications, including video games and handwriting recognition. With the ability to scan the touchscreen sensor every 4/1000 th of a second, your application can sustain a data report rate greater than 250 Hz. [60] The response from the SSDC device must be efficient and fast enough to let the user be notified of the incidents of any car theft and car damage occurring to their vehicle.

- Robustness - maXTouch devices are environmentally robust, so you can confidently design cameras and cell phones for harsh weather conditions. [60] The device will need to be robust in certain temperature and even during car crashes as the car can be subjected to high temperatures and harsh damage in the case of car damage.

- Range of Atmel AVR and ARM microcontrollers - Atmel provides 8-, 8-/16-, and 32-bit AVR and 32-bit ARM-based microcontrollers optimized for low power and 1.8V operation. Save time and money by taking advantage of the Atmel QTouch® Library for standard microcontrollers as well as easy-to-use, low-cost tools. [60]

- Highly Integrated Power Management - Atmel provides optimized solutions for Atmel AT91SAM ARM-based devices, including integrated DC/DC converters, low dropout regulators, real-time clock, and audio CODEC (compressor-decompressor), all controlled through industry-standard serial interfaces. [60]

4.10.4 Microcontroller Selection

The microcontroller that is to be selected have to be chosen such that it is able to function as necessary without being way past what is necessary. Thus, the microcontroller must be chosen based on clock speed, memory and the type of interfaces in which the microcontrollers can communicate with sensors, and other modules. Included in that is their ability to be programmed.

Part Number	Clock Speed	Memory	Communication Interfaces
TMS5703137DPGEQQ1	180 MHz	• 3 MB Program • 256 KB RAM • 64 KB Flash	• 10/100 Mbps Ethernet Mac • FlexRay • CAN controller • SCI • I2C • LIN • MibSPIs • SPIs

Table 9: Microcontroller Comparison

4.11 Mobile Platforms

Mobile applications are platform specific as each phone implements their own operating system, the most common of the two being Android and iOS; there is also a separate platform for windows based phones but due to it's low market penetration will not be considered for this product. In 2016, the market share for android held 84.3%, iOS held 13.4% and the remaining 1.8% to windows mobile [27].

Android

As the most widely used mobile platform in order to achieve the highest accessibility the mobile application must be available on Android. The open source nature of the platform allows for easier development and documentation and promotes increased resources. Development for applications on this platform require no separate purchases and remains completely free to develop for. The platform is a linux based distribution which allows for higher accessibility and utilization of underlying features of the device without advanced programming knowledge. Development for the platform lies mainly in Java, an easy to understand language that will be discussed later in this paper. The tool utilized to develop will be the android studio or Android developer tools, both which are free integrated development environments (IDE). Applications are published to the Google Play store to be available for download, in order to be able to publish applications to the store the developer must pay a one-time $25 fee. At which point publishing of any application will incur no additional costs.

iOS

The iOS platform for Apple devices maintains a high enough market share to require consideration for development. The platform utilizes a singular programming language, Swift, for all development. The language is based off of objective C (C#), and development requires the use of their proprietary IDE Xcode. The IDE requires the mac OSx operating system to run, thus reducing the ease of access for development. In order to publish to the Apple store the developer is required to pay a recurring $99 fee annually to maintain developer publishing access. Due to these restrictions the project will not implement an iOS version of the mobile application.

4.12 Languages

Numerous languages will be utilized in order to properly implement all required aspects of the product. The device has two critical software components, the embedded device and the mobile application. Due to the nature of these components, different languages will be required to be implemented. Choosing the best language for either component remains critical for usability and ease of development. Support and compatibility play vital roles when considering a language due to the restraints imposed by any microcontroller.

Python Programming Language

Python remains one of the easiest and streamline languages to utilize in development. The language lies at an extremely high and abstract level thus shielding the developer from low level interfacing that would be experience in languages such as C. This abstraction comes at the cost of increasing code runtime and thus reducing performance; the benefit being a reduction in development time. Another potential issue with python's high level is implementation with low level devices such as our embedded systems. Utilization of a form of python named "Embedded Python" or "CPython" will be required to bridge the gap of compatibility; running this platform will require running a lightweight distribution of linux. This will require more memory than may be available on the device and thus will require significant testing, if this appears to be the case utilization of other python implementations with a lower memory footprint such as PyMite or Zerynth may be required.

C Programming Lanugage

Traditional embedded devices utilize the C language for the code base due to the low level nature of the language. This allows for large compatibility as most high level languages are ported off of C. The language has a higher development time but will allow for increased runtime efficiency as well as a lower memory footprint. This language also will not require the use of an interpreter such as is the case with python, as C is a compiled not an interpreted language.

Java Programming Language

Android development revolves around the Java programming language, nearly all android applications are developed in this language. Java is a high level object-oriented programming language that will allow for streamlined development of the android application. The language itself runs in a virtualized container environment named the java virtual machine (JVM) and relies on the Java Runtime environment (JRE). Due to the courses provided at UCF this language is known and familiar to our team members and will reduce research time in the development lifecycle of the mobile application.

4.13 Hardware Suppliers

This section will review the utilization and comparison of numerous suppliers when considering both purchasing and sampling of numerous major components for the final product. Decisions regarding component manufacturers are based off numerous criteria prioritizing the ease of access of the component, the ability to receive the component, the simplicity for the design and utilization of the component as well as of course the price point for the component. A major concern for the development team is to keep cost low to make the product as appealable and marketable as possible for mass market. The simplicity and ease of access as well as documentation accessibility are critical when considering the development stage of the design.

The major providers the team utilized for this project were chosen due to that ease of accessibility. Such as Texas Instruments who graciously provides an easy method for receiving samples of their components. As well as the ease to accessibility of their products they have an easy to contact support as well various well documented sources for their components. These factors will be discussed in the following paragraphs.

Texas Instruments provides reliable hardware at competitive prices. The team will work with TI for WiFi chips, accelerometers, and MCU's. TI has some of the lowest power chip sets around. This project requires low power consumption chips because they will be running on the car battery. Another chip supplier of the team will be Ambarella or Novatek for their video processors. These chips make it easy to process images and video from a recorder. This will save the team development time but increase the chip price. Intel will also be a supplier because of their large chip sets of FPGA chips. These chips are a low cost way to design a video processor instead of buying a pre programed one.

4.14 Online Data Storage

The device will need to speak with a cloud server for the data storage aspect for both videos and logging of certain information related to the devices. Cloud storage is provided as a service to the user and is abstracted from them through the use of a yearly/monthly service fee. This section is the research related to choosing a cloud storage provider based off factors such as cost, scalability and ease of use. The following sections will make assumptions based off setting a standard of 1TB of cloud storage per user. All analyzed costs must be achievable and marketable to a user as part of a monthly fee, without online storage the device will be limited to local storage.

4.14.1 AWS

Amazon web services remains the most widely utilized cloud provider for both data storage as well as utilization of cloud servers. The data server for communication would be able to be implemented in this platform along with the cloud data storage. Due to the large usability of the platform the ease of utilization and accessibility will outperform most other providers. The documentation and automated tools revolving around AWS also is of the highest quality due to their wide spread. The platform itself can be easily scaled as they are capable of hosting full enterprise environments with ease, many companies such as Disney are porting entire environments to the AWS infrastructure.

The most critical aspect of all factors lies in the cost of storage per user. For amazon standard storage costs the AWS S3 storage can be seen in the below screenshot.

	Standard Storage	Standard - Infrequent Access Storage †	Glacier Storage
First 50 TB / month	$0.023 per GB	$0.0125 per GB	$0.004 per GB
Next 450 TB / month	$0.022 per GB	$0.0125 per GB	$0.004 per GB
Over 500 TB / month	$0.021 per GB	$0.0125 per GB	$0.004 per GB

Figure 18: AWS Storage Costs

Utilizing the assumed data storage of 1 TB per user the cost per month for each user in storage cost would be $23.552 or $282.624 per year. The costs may be able to be reduced utilizing regional servers. During product testing phase they provide one free year of cloud storage suitable for the testing phase.

4.14.2 Dropbox

Dropbox has the strangest pricing and storage requirements of all of the listed companies. They don't deal with conventional cloud environments and charge for a per user storage basis. In our case only a maximum of three user accounts would be required at a cost of 25 per user per month. The issue resulting in the requirement of requesting more storage when the data per user goes over 1 TB. While the state unlimited data testing would need to be performed utilizing the 30 day free trial provided, in order to determine if the statement is completely valid. If it is possible, beyond the low bandwidth of the storage the cost per data would be astronomically inexpensive.

They also have a hurdle when it comes to ease of accessibility, as they do not support the utilization of file syncing with a server. In order to accomplish this development would need to be performed for implementation.

4.14.3 Google

Another well known and utilized company, but not in the cloud storage space. They utilize a different format for their cloud storage pricing scheme. Unlike amazon they do not charge for network usage or file access, their pricing depends solely on storage usage and thus have a slightly higher price per GB of storage. Through this process no unaccountable data costs will be reached with over access of the network.

Multi-Regional Storage (per GB per Month)	Nearline Storage (per GB per Month)	Coldline Storage (per GB per Month)
$0.026	$0.01	$0.007

Figure 19: Google Cloud Storage Costs

Utilizing the assumed data storage of 1 TB per user the cost per month for each user in storage cost would be $26.624 or $319.488 per year. The costs may be able to be reduced utilizing regional servers. During product testing phase they provide 5 GB free storage for a year.

4.14.4 Local Storage

The option most likely to be utilized in the project for low user base remains local storage. While this forces a higher burden on the development team for setting up access to storage the cost is tremendously decreased. The cost would be outweighed if the hardware was not already accessible to the team, a usable server from a previous employer of one of the team members provides access to an older but functional server. The storage space of the device accounting for approximately up to 3 TB. The only true cost to the team would be development time to ensure setup is completed alongside the cost of electricity, a minor cost in comparison to other providers.

While this option is both affordable and sustainable for the development phase the product would be forced to migrate to cloud providers for a higher user base as the cost of acquiring new hardware outweighs potential profit margins.

4.15 PCB design research

The following section of the report discusses the reasoning behind the internal design and material choices for the SSDC PCB while addressing solutions to issues that arise during PCB creation. Proper setup for a PCB increases its life expectancy and overall performance. When considering materials for the SSDC PCB it is important to address certain aspects of the environment in which the SSDC will be located, or issues such as thermal shock could potentially damage the device. Selecting the correct materials and proper placement of components for the PCB can increase life expectancy of the product as well as negate certain issues before they ever arise.

4.15.1 PCB Base Material

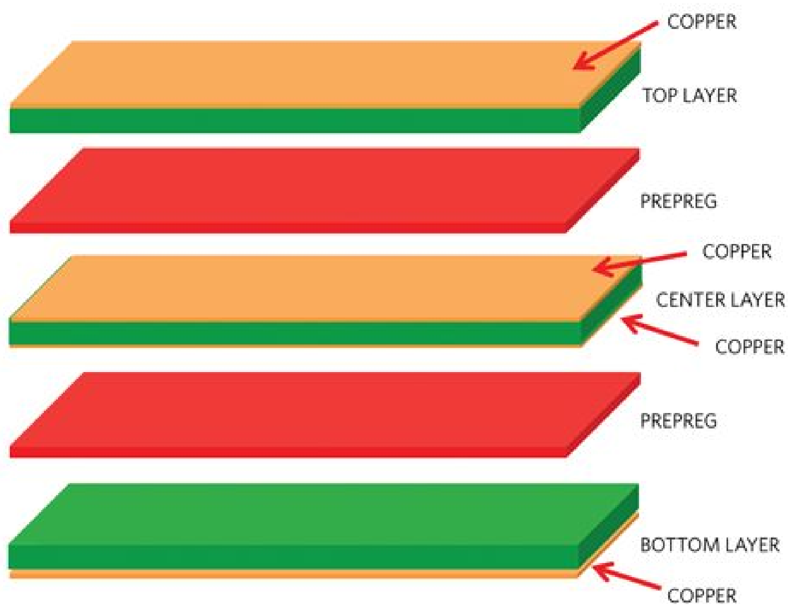


Figure 20: PCB internal view (Permission pending) [54]

Substrate Materials:

- **FR-4 -** The material FR-4 is a reinforced laminate sheets used to produce the cores in PCB boards illustrated by the green substrates in Figure#. The FR in the title refers to Fire retardant, and is typically followed by TG###. The TG### refers to the transition glass temperature of the material, and the ### is a number that represents the temperature where the reinforced glass temperature becomes deformed or softened. FR-4 is the standard in the PCB manufacturing industry for material design in the sheets. It wide use also makes it one of the cheaper options for material in boards. The FR-4 material is used to create the isolation of the copper sheets.

- **G10 -** G10 is another core material that is used to separate the copper layers in a PCB similar to FR-4. G10 is a high pressure fiberglass laminate material created by binding multiple layers of glass cloth and soaking them in epoxy resin. G10 has essentially been replaced by FR-4 due to FR-4 being safer, and this is because G10 is not flame resistant. G10 is now typically a special case use of material in PCB, and in general is being phased out for FR-4. G10 was considered as a possible material to use in prototyping due to it's lower cost.

- **FR-2 -** FR-2 is a core PCB material that is an outdated version of FR-4. However, even though FR-2 is an outdated form of FR-4 it is still used for low cost production when high quality is not needed, or when large environmental changes are negligible. Of all the material on this list FR-2 is the cheapest material option on the market at the cost of being less reliable.

- **Aluminum -** Aluminum is a higher class more costly PCB design material. Using aluminum for PCBs requires a copper layer being placed then a dielectric then the aforementioned aluminum layer. Aluminum is a more costly design choice, but provided some benefits other materials do not benefit from. The Heat dissipation in an aluminum board is dramatically superior to the previously mentioned FR-4. The dielectric used are five to ten times as thermally conductive compared to G10 or FR-4 at only a fraction of the thickness. Thermal transfer is more efficient, and lower amounts of copper can be used compared to other insulating material. Aluminum is being considered for when the SSDC goes to market, but the hindrance is the increase in price.

4.15.2 PCB

The SSDC is expected to have 2 to 4 double sided copper foil layers illustrated by the copper foil in the figure above. For the copper layers of the SSDC PCB design the choice will be 1 ounce per square foot. The amount of copper on PCBs is measure in ounces per square foot, and the more copper on the board the better the power dissipation becomes. However since the board will not be high powered 1 ounce per square foot should suffice. The spacing for the board will be 6/6 mil. The board itself is expected to be 1.6 mm thick, and the vias connecting the different layers of the board will be tented so they are not improperly soldered.

4.15.3 Vias

When constructing a board in Eagle there is typically a need to drill holes in boards that are more complex. These holes are called vias and connect different layers of a PCB together through copper tracing. In more complex PCB design it is sometimes extremely difficult or altogether impossible to have all the necessary traces on a board without crossover or shorting something. To simplify the tracing of a PCB holes can be created to jump around the different layers, but have many vias in a design is typically frowned upon.

4.15.4 Silkscreen

When the board is designed it is typically marked on the surface with a silk screen which is essentially a substance acting as ink to add markers to a board. These marks on the board can indicate placement of components warnings or manufacturer logo and labels. Typically a manufacturer will typically provide a manufacturer’s mark unless told not to by altering the files in the gerber file.

4.15.5 PCB surface finish

The surface finish of the SSDC PCB will likely be HASL which is popular coating for PCBs which goes on the top and bottom of the PCB. The surface finish is typically not given as much attention as other parts of the PCB however improper selection of surface coating can cause thermal shock or cause other issues to the PCB board if not accounted for. The HASL is a low cost choice for surface coating due to its popularity, and its ability to be repaired. This is likely to be what is used for the senior design prototype, but in future marketed designs of the SSDC a tin immersion coating would be more optimal for the environment in which the device will be located.

4.15.6 PCB Pads

The PCB pads are the areas on the PCB not covered by the silkscreen. These are where the components will be soldered to the board. These are very important because if they are covered up it will be very difficult to solder properly. For the project the standard pad size will be used; however this sometimes needs to be shrunk or increased depending on components and applications. Pads can come in different versions as well with through pads as well as the more common surface mounted pads.

5.0 Design

5.1 Hardware

The following chapter discusses the design choices and reasoning beyond isolating the component choices while including all necessary tools involved with the development. Development choices will also be considered such as the UI design and the reasoning behind these choices. This section will also detail the full project in hardware design and construction as well as any pitfalls that may need to be discussed through our decisions and physical mistakes. Identifying these pitfalls allow for the product to evolve and improve the product, ignoring these mistakes would lead to potential repetition in other aspects of development.

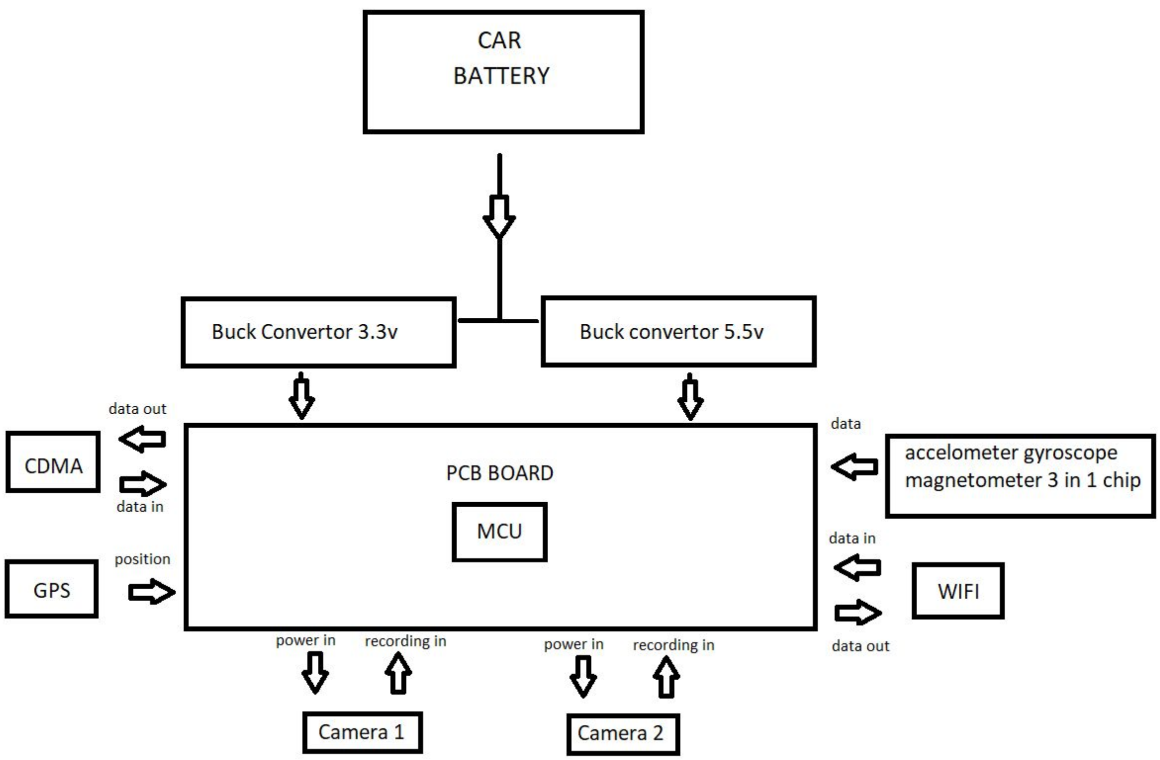


Figure 21: Block diagram

5.1.1 Design

Consumers who will purchase the SSDC will not typically be engineers or skilled mechanics. Keeping this in mind the device will be made with simplicity and safety in mind. This will be done primarily through two methods; having the device initially professionally installed, and also making the application simple/easy to use.

The purpose of having the device need professional installation is for safety, simplicity, and liability. The SSDC will need to be attached to the car battery directly meaning that the device will have to go through the interior of the car, and the firewall separating the interior from the engine. Having a professional install the device prevents the consumer from unintentionally damaging their vehicle’s crucial firewall, and as a result possibly saving their life in future accidents. Professional installation also removes some liability from DEUCE because the installation will typically be done by a mechanic of the consumers choice, and any installation issues will be the result of their professional ability. The device will also be professionally installed to simplify the process. Having to professionally installed can seem counterproductive to simplicity. However, keeping in mind most people are not auto mechanics, and there are safety constraints that need to be kept in mind. The simplest choice for the average consumer is to allow a professional to install the device.

The physical design of the product is intended to achieve a minimal impact on the driver's view while still maximizing the camera’s view and angle. The design should be both minimalistic as well as small as possible. The company logo should be visible from the exterior of the car when looking into the windshield to serve as both an indicator of added security and provide marketing to passer-bys. The final design may be larger than the intended project due to design inexperience but is hoped to be improved after the first revision of the product. Utilizing the experience gained from the first development as well as integrating smaller and more compact components to the device. The product will be design to fit on the rear-view mirror of the vehicle without the assistance of an external mount or provided mount. Two clamps on both sides of the device positioned in a similar method as a bracelet or watch, will wrap around the rear view mirror in order to provide a comfortable and secure fit. The device will under this design experience as much distortion and shake as created by mirror itself. One camera will be facing towards the interior of the vehicle right above the top of the rear view mirror in order to provide view as well as avoiding compromising much of the physical mirror as possible. The second camera will be placed facing the exterior of the car out through the windshield, this will be located on the rear of the rear-view mirror in order to provide the view of the vehicle surroundings and road. The design should impact a very minimal portion of the driver's view as well as not create any unsightly device. We determined that most care users would prefer their vehicle to be uncluttered with bulky devices such as a dashboard camera, and thus minimizing the user's view of the device maximizes the product’s appeal to customers. A rough sketch of the potential design before 3-d modeling can be found below.

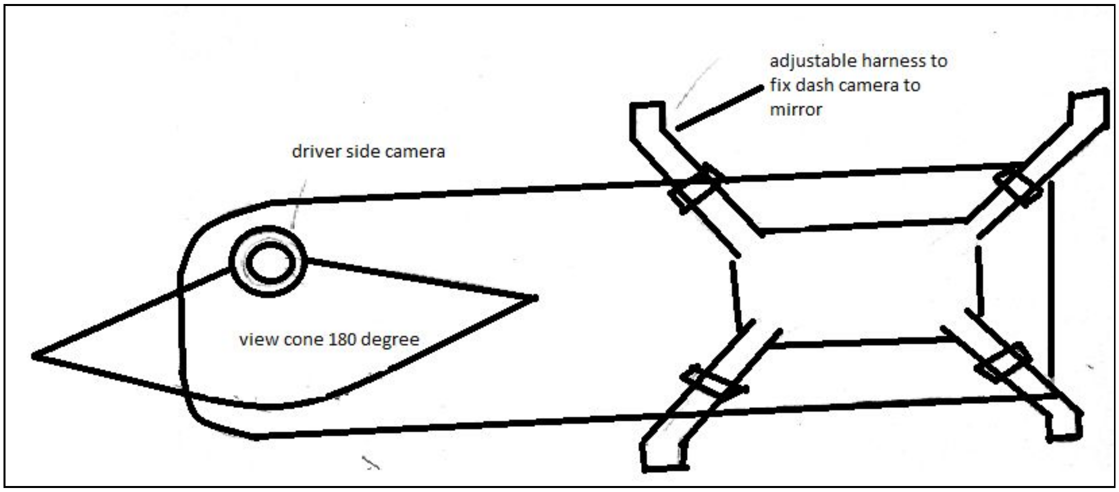


Figure 22: Driver view SSDC

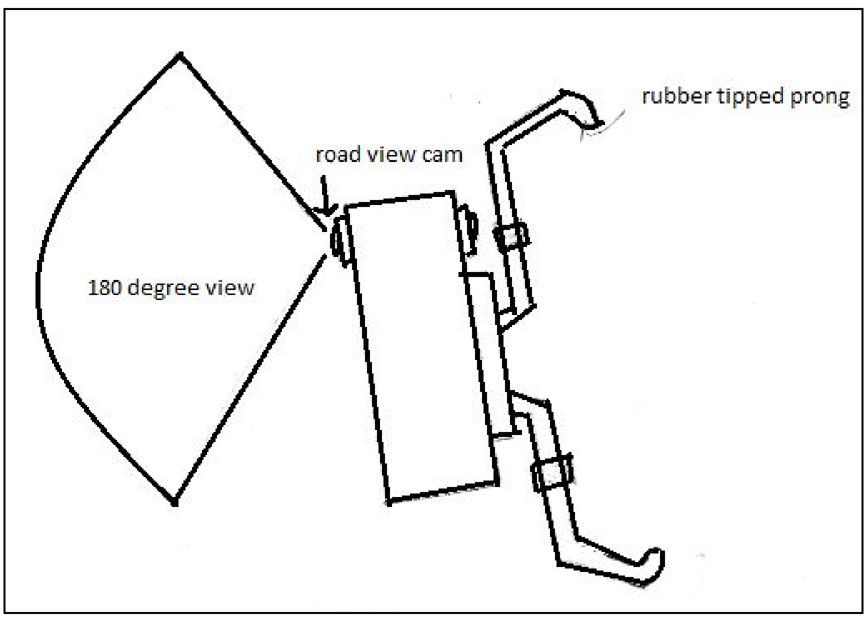


Figure 23: Side view SSDC

5.1.2 Development Tools

Software	Specs	Price
Eagle Premium	99 Sheets, 16 Signal Layers	$100 per year
Altium Premium	99 Layers, Unlimitated	$7245 per year
Orcad Free	2 Layer, 500 pins	Free
Eagle Free	99 Sheets, 16 Signal Layers	Free
Altium Trial	Unlimited	Free for 15 days

Table 10: Possible PCB Dev Programs Cost Analysis

5.1.3 Altium

Altium 14 is a PCB design software created by The company Protel. It is a comprehensive software for both the design and creation of PCBs. The software first allows the generation of a schematic for the potential circuit board, and once the schematic is completed the circuit board can be accessed and the components loaded. Before the components and board are laid out for placing the program shows a list of all modifications done to the schematic design giving you full authority over what was designed. The program also gives the ability to bring full designs from other CAD tools by following their program guide wizard. The Altium designer is a versatile well supported program with many features that is highly supported, but the program costs a staggering $7,245 as posted on their site. A free trial version of the software is available, but the program is very limited in the amount of time that it can be used before the program is locked.

5.1.4 EAGLE

PCB design programs can have both a high cost and high difficulty. The program that was chosen for the design of the PCB in the SSDC is Eagle. Eagle is a PCB design software that allows for the creation of multi layer PCB designs. The program also offers auto routing of the created board using advanced mathematical equations to try to find the optimal etchings for the placed components. The choice to go with Eagle is both an economic choice see that Eagle offers a free version of their software for students with an active school email, and also because eagle is well supported by many companies meaning that many components on the market already have eagle compatible designs. This is very important because the creation of components in software such as Eagle can be a very tedious project especially if it needs to be done for more than one component.

Eagle Operation: The operation of the eagle program will done in two parts first the PCB will be designed in a schematic format on the eagle program then the components will be placed on a board in a .br file. The schematic and the components in the .br are intertwined; meaning that if you create a component in the schematic portion of the program that component will appear for placing in the .br file on the simulated PCB board.

The first part of the creating of a PCB in eagle you have to create a schematic. This can be done by opening eagle, right clicking the project manager and selecting new project. Then select the location for the new project. This location will hold both the schematic file and the board design folder as well as a file that connects them. Once this is done the schematic of the board can be designed, and when components are added to the schematic they immediately show up on the board design for placement and wiring. Since the added component shows up instantly the wiring/placing of the board components can be done all at the end throughout the duration of the schematic design. To add components to the board select the add button located on the left side of the program or under the edit menu. From here components can be selected. When searching for components entire families can be searched by using a * on a search query. The next thing you need to do is to create a frame which isn't mandatory to have, but looks more professional. Adding the desired components is simple enough select the component click once and it appears. Now once all the components are place put any power supplies needed by the design. Once all the components that will be used are on the board the they have to be wired together. This can be done via the wire tab located on the left side of the program. This is typically a straightforward process, but caution must be taken when wiring. This is because while the eagle software does report issues in a design if you incorrectly wire over something such as a mosfet the program will not consider this an error, but instead it will consider this a chosen design. Since this will not be reported as an error this may be overlooked, and as a result the board may be fabricated as is resulting in problems later on.

5.1.5 Printed circuit board

The schematic of the layout PCB for the SSDC will be finished early at the start of the second phase of senior design, and will be created early afterwards so that testing can begin. For the PCB that will be in the SSDC the board will be designed then professionally manufactured. The choice to have the board be professionally manufactured is to reduce risk of creation errors of the board. Also there are some relatively cheap options offered to students for the soldering of components and board manufacturing. Time has also been considered when designing the PCB, and considering that there is a large amount of work that can only be done once the board has been designed it was decided that there is no reason to risk any errors hand soldering components. Thus the PCB will be designed, sent out to be fabricated, and then brought to a local company to have the components soldered.

5.1.6 PCB Design

As stated earlier the chosen design software for the layout of the PCB will be Eagle. Once the board is designed completely, and no error have been reported the board will be saved and exported. Eagle has an export file called Gerber that allows for many PCB manufacturers to see the specifications of what the board needs. These files are accepted at most PCB manufacturers, and simply layout the board for the manufacturing process. Many PCB manufacturers even have an upload section on their sites for gerber files to provide an accurate estimate of the cost to manufacture. However if there are any errors in the board that show up before manufacturing takes place the board will be declined. Also if a wire is misplaced in the design of the board but no error is detected the PCB will be manufactured and will be assumed to be an expected feature resulting in a possible short. This means the design of the PCB has to be essentially perfect before exporting the gerber files to a manufacturer, or you will pay for and receive a very costly worthless piece of silicon and copper. Also seeing that many manufacturers require a minimum of 5 PCBS be made to create a design the economic burden will be even furthered if the design is off.

5.1.7 PCB manufacturers

When selecting a manufacturer for PCB manufacturing a few key things were taken into consideration as the main considerations when choosing a manufacturer. These key considerations are Allowable board thickness, maximum allowed sized allowable size for all desired components, tracing options because the width of the traces will be important with the high frequencies in the system, allowable number of layers, price estimate through online quotes, creation time since time is need to test the device, and customer review quality of manufacturers. When considering these points custom setting for order were not considered, and the estimates provided are based on the standard creation options. This means that many of these manufacturers offer more advanced options such as number of layers or tracing, but the tradeoff is a much higher cost due to the need to change the mainstream process. Certain qualities were considered from the custom setting for this project, but it was determined that the SSDC will not need extreme customizations to perform at the desired quality level. Also another very important thing to make a special note of is that increasing past certain sizes as well as jumping to 4 layers increases the price of a PCB radically.

PCB manufacturer	4PCB	PCBway	PCBcart	SEEEDStudio
Board thickness	.031 to .125	.4 to 2.4 mm	1.6 to 3.2	.6 to 3mm
Allowed board size	1200	1200	1200	1200
Tracinng option	4/4 to 6/6 mil	5/5 mills	3/3 to 6/6 mils	4/4 to 6/6 mils
Minimum quantity	1	5	1	5
Max layers	10	Unlimited	Unlimited	Unlimited
Price estimate	$80	$60	$100	$65
Deals	none	5 dollars off	none	none
Creation time	Same day to 7 days	Same to 5 days	7 to 18 days	5 to 6 work days

Figure 24: Comparison of multiple PCB manufacturers

4PCB

4PCB is a manufacturer based out of the US that manufactures PCBs on all levels supplying orders of singular pcbs to tens of thousands of PCBs. 4PCB offers standard specifications for boards up to 10 layers, FR-4 material, 5/5 mill tracings, and .031 to .125” board thickness. 4PCB also offers a 50% discount for first time customers making smaller pcb quantity cheaper than typical.

PCBcart

PCBcart is company based out of china that has been providing PCBs for 14 years. PCBcart offers specifications up to 3.2mm thickness, FR-4 material, single or dual panel board, and up to 1200mm squared board size. PCBcart also offers an online projected quote for their boards, and early estimation of our boards specifications puts their quote around 90 to 100 dollars for the board.

PCBway

PCB way is a PCB manufacturing company based out of china. PCB way offers a variety of manufacturing specification options. PCBway offers multiple board materials including aluminum, FR-4, and rigid flex. They allow up to 12 layers, and a thickness of up to 2.4mm. There is also an option for tenting or plugged vias. PCBway's online projected quote estimates our board to be around 58 dollars. PCBway also offers a 5 dollar coupon to first time buyers which reduces the price some. However, they have a minimum requirement of 5 boards be ordered.

SEEEDSTUDIO

SEESDSTUDIO which will be referred to as SS is a PCB manufacturer that offers PCB development as well as assembly. SS offers typical options for PCB manufacturing with standard FR-4 material, up to 3 mm thickness, up to 6 layers, copper up to 3 oz a square foot, and track spacing down to 2/2mil. Their estimated quote for the SSDC PCB is around 90 dollars USD for a minimum quantity of 5 boards without assembly.

5.1.8 PCB housing

The housing for the electrical components located on the PCB need important consideration due to the environmental issues based on where the device is located. These issues are are a result of heat, and the forces exerted by the acceleration and deceleration of the vehicle in which the SSDC is located. The case for the SSDC has to be able to withstand a variety of temperatures as well as fast changes in temperature caused by the air conditioning changing the internal of the vehicle rapidly. Not properly selecting a material capable of withstanding these temperature can cause cracking of the housing, and exposing the internal sensitive electrical components. Also the casing for the SSDC has to be durable able to ideally withstand a car minor to medium car accident or else the product will not be able to function as it is intended to. A possible solution to these design issues is to make the casing of the SSDC out of fiberglass which can handle radical temperature based on material chosen as well as handle physical abuse of a minor car accident. The downside of this is the look of fiberglass is not an exceptionally attract look for the product. Regardless of what material is selected the PCB along with the camera components will be secured to the external frame through indicated points on the PCB board by the use of screws.

5.1.9 Reasoning for wireless/4G

When considering whether to use wireless or data it was decided that both systems will be used on the pcb. The system will be sold as wireless with the ability to activate the 4G if the consumer wants the ability to access the cloud anywhere. When trying to choose if only one or the other should be implemented the wireless had the lower cost to the customer, but the 4 G has most versatility.

The 4G was feature originally designed for the device, and can be used to send footage to the cloud in most locations. The idea behind the 4G design was that in the event of an accident should the device become damaged the footage will still be available in the cloud for review and access. In addition, having the 4G activated would allow the system to notify the owner in real-time if there was an accident involving their vehicle, or provide real-time position tracking if the vehicle was stolen. This data could be relayed to law enforcement to greatly reduce the time it takes for the police to intercept the vehicle, reducing the potential damage the thief could do to the vehicle. By including 4G in vehicle it also allows for the tracking of the aforementioned vehicle via gps tracking resulting in the recovery of any stolen vehicles.

The initial use of wifi on the board was chosen for both economical reasons as well as a local use. Many people who would use the wifi only version of the dash cam would ideally be parking the vehicle somewhere within range of their work or home wifi. The dash cam still operates as a deterrent to theft because the wifi model is the exact same as the 4G version of the SSDC, so a knowledgeable thief will consider it on the same level protection. During driving the data will be stored on the devices' ssd card until it comes into range of wifi, and transfer the data to the cloud. This is also less of a concern due to many devices being able to become hotspots allowing the SSDC to function similarly to a 4G model when utilized external devices such as a cell-phone.

5.2 Software

The following chapter discusses the design choices and reasoning beyond isolating the component choices while including all necessary tools involved with the development. Development choices will also be considered such as the UI design and the reasoning behind these choices. This section will also detail the full project in hardware design and construction as well as any pitfalls that may need to be discussed through our decisions and physical mistakes. Identifying these pitfalls allow for the product to evolve and improve the product, ignoring these mistakes would lead to potential repetition in other aspects of development.

5.2.1 Android Application UI Design

The simplicity of the device will also be extended to the software. To simplify the software for the device the application controlling the camera will include only necessary software that is believed to be necessary, and functionally optimal. Crucial elements include features such as alerting and video recordings of potential intruders or damage to the vehicle. As well as giving the option to live stream the video camera's output to the mobile application with no quality degradation and minimized latency. The simplicity of the application keeps the SSDC functional while not becoming cluttered with unneeded additions that already exist in pre-existing applications.

As stated previously the application design needs to remain simple and elegant as users prefer simplistic designs with low learning curves. All crucial features need to be quickly accessible from the main menu through a singular touch such as the live feed, settings and relevant statistics. All submenus such as the wireless settings under the settings menu should be no farther than two touches away from the home UI. The design mentality throughout development will be that no one feature should be more than two touches away from the home screen, minor exceptions will be made for some sub-features such as video editing. The first phase of development will provide a lackluster design but the barebone UI will exist under a minimized design lacking graphical dressing. A sketch of the potential main UI can be seen below, from this menu the user should be able to access all required applications from a singular point.

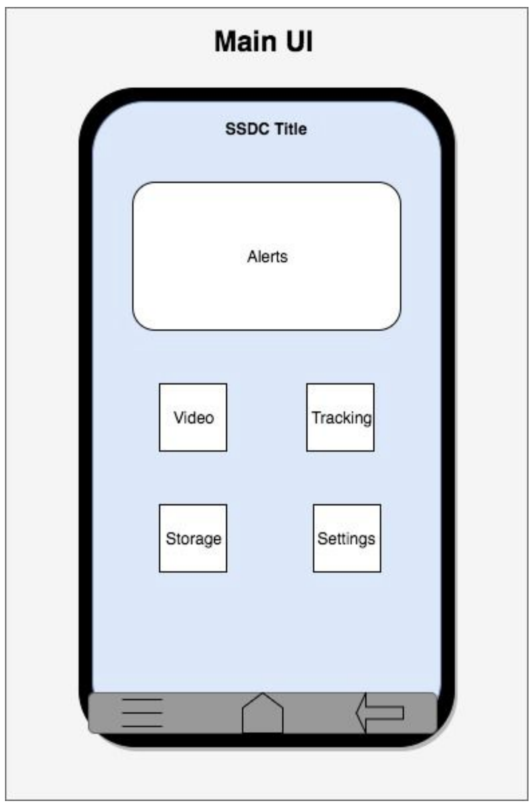


Figure 25: Design Interface Mock-up.

5.2.2 Development Tools

Android Development Platform

The android platform provides a simpler means of production for newly started products due to the availability and accessibility. Android utilizes the Android Package Kit (APK) format to allow for easy installation of applications on linux based devices. Development of the android application will be wrote in Java just as most android applications are developed in this language. Android Studio will be utilized in order to create the application, utilizing the provided android simulator to perform quality assurance testing of the application during the development lifecycle. The virtualization of the android device through the use of the integrated development environment increased productivity and efficiency as well as accessibility during the testing and debugging phases, potentially saving tens of hours. As well as allowing for the application to be tested against a variety of android operating system versions and flavors beyond a singular distribution that may be available amongst the team members.

Operation of Android Development Platform

The development of the application through the utilization of Android Development Studios remains straightforward. The application will be designed incorporating the design constraints such as the two click design as well as simplicity paired with runtime restraints. With those restraints in mind the application will be developed through standard means through the use of the IDE. Once a runnable application is produced the application will then be tested utilizing the simulation service provided by the integrated development environment for the first few tests. After a more acceptable product is developed the application will be tested utilizing physical Android cellular devices owned by the team.

Python

When considering what program to use to program the PCB board for the SSDC a few key points were addressed. These included simplicity to increase productivity, familiarity to prevent a needing to learning a new language, and cost to prevent to large of an entrance fee, and support so that the program is up to date and compatible with most software platforms. Python is a high level language programing software that was chosen for for the programming of the SSDC board. Python is an easy to use object oriented software that supported across Windows, Linux, Unix, and MAC OS X. Python program is copyrighted, but the program is currently free under open source. Currently python is known to some members of this group and well as other languages, if python is not known directly it is an easy transition from C programming. Python has a vast amount of programs that currently exist from many uses which reduced the amount of smaller programs that need to be created from scratch. Python also has fewer complicated steps to programming than other languages, and has a very interactive error system that allows for testing smaller code segments. The derivation of python that will be utilized in this project will be a form of embedded python called micropython, cpython or Zyneth. All are different ports of embedded platform that are intended to be ran on supported microcontrollers, the choice on which port of the language utilized will be determined after testing the platform on the microcontroller.

5.2.3 Development Lifecycle

In order to ensure an appropriate product lifecycle as well as standardize the development process for future use the team will follow a standardized software development lifecycle. This will ensure congruity amongst the team when developing the initial prototype as well as the finalized product. The lifecycle aspect comes into play when considering both new products as well as the addition of new features; that along with the integration of version control create for a streamlined and modular design methodology to maximize the team's efficiency.

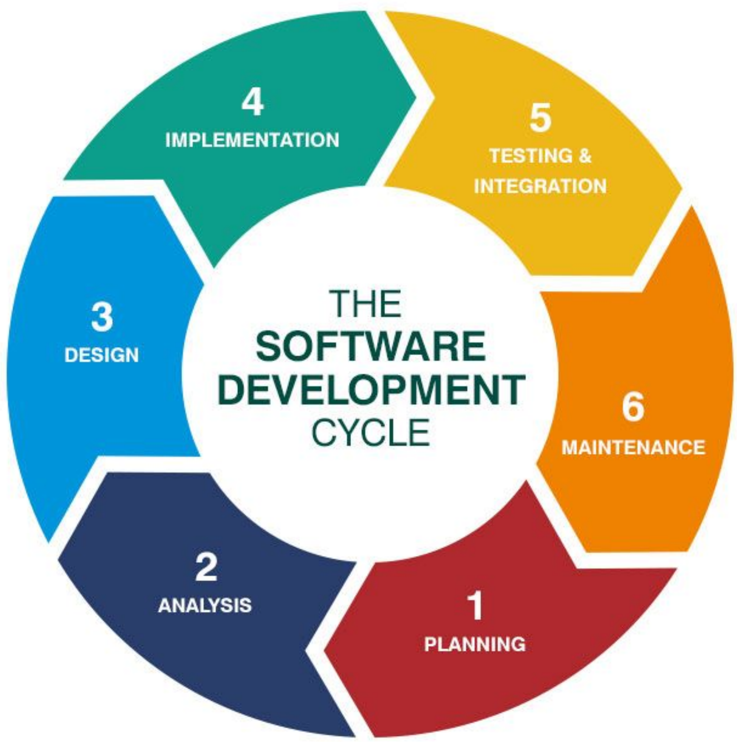


Figure 26: Development Lifecycle (Permission Pending)[47]

Most developers in both enterprise and startup scenarios define and utilize the development life cycle to ensure products are appropriately developed in a timely and monitored matter. There are typically six stages to the software development life-cycle as can be seen in the above figure. The four important aspects of which for us will revolve around: Planning, Design, Implementation and Testing; these are the most critical components to ensure a working product will be released. The planning stage is covered through our research section of the paper, ensuring that all possible critical components and technologies as well as potential suppliers are understood and noted.

The design stage involves the utilization of any applicable SRS or design restraints to ensure the product meets a baseline qualification as well as provide high level documentation. It creates the outline for the actual implementation of the application, high level documents such as data flow diagrams, PEP diagrams as well as process diagrams. The implementation stage is when the design takes the physical form and where the bulk of work is completed. The actual application design begins implementing the high level diagrams into a lower level form of actual physical code.The design section is what is covered in this chapter involving the implementation of our planning and highlighting major features that need to be implemented; within this same chapter we cover the implementation as well, major features will be discussed at an implementation level as well below.

Stages one, three and four will ensure you have a product or prototype built but to complete and ensure a working product you must implement testing and integration, stage five. After implementation there will potentially be pit-falls or bugs that may be hard to detect in development, thus testing must be completed to discover, observe and resolve these hidden issues. Not only is it critical to the functionality of the device, the testing stage provides valuable insight in any missing features as well as any potential integration issues that may arise. During this stage it is potentially beneficial to receive outsider insight into the product, possibly perform a case study and get the device in the hands of beta-testers. For the project at hand this stage may be considered our submission and demoing the device at the end of Senior Design II.

Following the life-cycle in the manner discussed above with the correct team produces the product efficiently. The following sections will keep this development life cycle in perspective and the team followed this methodology throughout the development stage of the product.

Version Control

An important aspect of the development lifecycle is reliable and appropriate version control. Version control is the mechanism utilized to ensure that the software may be operated in both a communal manner as well as ensure that the software is safely stored outside of a local drive. This also allows for the forking of new versions and if an issue occurs in one version then the code base may be reverted back to a known working version of the code.

The most popular framework for version control and the one utilized in this project is GitHub. The framework is widely used in both enterprise as well as personal projects due to the simplicity and ease of accessibility of the framework. Most engineers, especially those team members in this project are familiar with the platform thus allowing for an easier development phase in the product lifecycle. The project’s code base is stored in a private repository, a repository being the master codebase of a singular application, on GitHub that may be forked by each individual team member.

5.2.4 Data Flow Charts and Diagrams

This section depicts numerous pictorial representations of key parts of the application and the interactions on the software portion of the product. These diagrams are representative of the the planning and design stage of the software development lifecycle. They represent the functioning of the application as a whole, and should provide insight on the high level workings of the application at an easy to understand level. The diagrams themselves for the most part are created utilizing the draw.io software and do not follow one set diagramming methodology.

The flowcharts and diagrams are meant to represent the coding structure of the SSDC device, and give insight on what needs to be put into the code. These flowcharts and diagrams are meant to be general and not specific as to only show the basic structure and design of code, such as representing what objects and functions need to be provided, and what she be stored in the database provided for the device. An example of this would the use case diagram, which is meant to show the basic functions between the user and the database, and between the database and device. This includes sending and receiving notifications with recorded footage and images and sending them through the database from the device through means of triggering the device. This also includes the user’s basic functions on the mobile application such as viewing the live recorded footage and GPS locator. Another example is the class diagram which includes a view of the objects and its functions that are used to interact with each object. Each object has its own attributes and types, as well as its functions. There would be different types of arrows to represent the types of relationships between objects. The attributes will be used to describe the characteristics and data retained in that object, while the functions will be used to interact with different objects as well as retrieve or send the data from the attributes. Hence why the attributes are also viewed as variables as they include data types as well.

(Note: These diagrams do not represent the final design or should be taken literally on how the code and software will be implemented. Most likely, the code will implemented and changed to better suit the design and functions of the SSDC device and its requirements.)

Software Communication

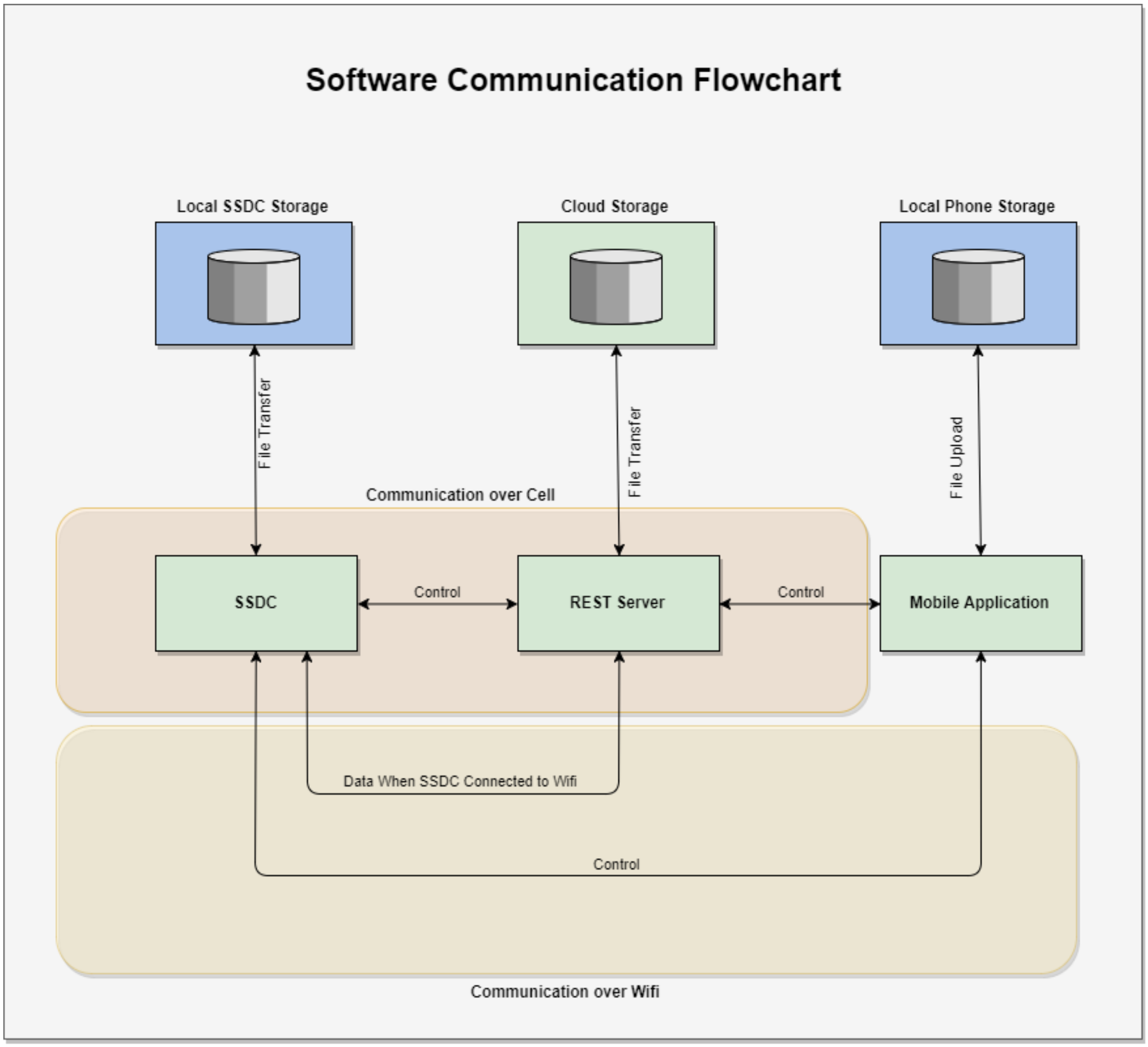


Figure 27: Flowchart depicting software communication

The above diagram illustrates the communication between all four separate hosts: the smart security dashboard camera, the REST server, Mobile application and the cloud storage server. Green boxes represent separate hosts, host's that are not connected by a physical device, and the blue box represent local internal objects to the device. In the case above only the local storage is represented for the mobile device. The numerous lower opacity boxes behind the diagram illustrate the means of communication for the devices, a yellow tinted box as stated represents communication of wireless; this wireless communication may be over the SSDC local hotspot or for the case of the SSDC over a connected wireless network to the device. A light red tint represents the device communication over the cellular service of either the mobile device or the cellular chip on board of the SSDC device. No tinting represents that the means of communication is either local or general communication methods specific to the host, in this case most likely general ethernet.

When the mobile application needs to speak to the device and is not connected over wireless directly to the device, the application must send the request to the server over it's data communication method; from there the central server forwards the request over to the SSDC through its direct communication channel, assuming the SSDC device has network connectivity. If the connection fails the server will return connection error to the application and will not retry to send the request more than three times before returning the error. The reason we don't continuously attempt to send the request as we would potentially encounter conflicting requests that may lead to internal errors; It may be possible that a few crucial requests such as commands issues to upload the stored files to the cloud will be logged and sent once connectivity is reestablished.

The SSDC utilizes the SoftAP technology in order to create a virtualized wireless hotspot for the cellular device to connect to and allow for the mobile application to directly communicate with the device. During this process the mobile application will receive an ip address dynamically while the device itself acting as the gateway will have the static internet protocol address, meaning the IP address will remain the same whenever the hotspot is enabled, the addresses utilized will be 192.168.1.1 or 10.0.0.1 as is standard. When the mobile application is directly connected to the devices wireless hotspot, direct communication through the hotspot will be established. A communication channel for the data transfer will be created and utilized to communicate between the two devices. All possible functions such as live stream will be handled directly through LAN communication, such as the live camera feed and any control interactions. This will allow for the application to receive the data and vice versa with the least latency between the communications amongst all the other communication methods. The downside of this is that it requires the user to be within a small range of the vehicle.

The device may be connected to an external network through the utilization of either cellular or wireless. When the device maintains connectivity through wireless the device is capable of sending all of its requests directly through a traditional network setup; meaning that the device may utilize traditional protocols for communication such as tcp/ip and built on top of that the HTTP protocol. The hypertext transfer protocol (HTTP) allows for a streamlined and easy to use communication protocol to a REST api server. The data just needs to be formatted and authenticated to JSON then sent to the servers load balancer or directly to the server. The server then can process that data and then any required information through to the mobile device requesting the information.

If the device does not have accessibility to a wireless network such as the case in remote areas, the device will automatically default to cellular data as possible. This situation provides the most difficult communication challenge as the device must be able to receive data and commands from devices that do not know the devices location as cellular has no IP address associated with the device. This challenge enforced the need for a remote server to act as the communication liaison between the mobile application and the SSDC device. The device will open up a communication channel in order to avoid polling if possible, with the remote server. The server will associate the connection with the correct mobile user and forward all control commands to the device and any data to the associated mobile application.

The final communication occurs when the device is unable to establish a communication channel via either wireless or cellular data. This will force the device to utilize the base interactions and store any data to the local device storage. All interactions and decisions for the device are then handled by the underlying programming of the device.

Data Flowchart

The data flowchart shown below is a representation of how the code will implemented to control its flow while it is running. Since the SSDC device requires specific triggers from the sensors and the SSDC device to respond to user inputs, controlling the data flow is essential in order to meet the requirement specifications for the device and have it function the way the developers have intended.

For this data flowchart, there will be conditions for each object and function before having the data processed. These can be if, if-else, and else statements or interrupts within the SSDC device. These conditions will be met with either a true or false value (yes or no). These conditions do not necessarily mean that the given data are only true or false as for example, the sensor data, from either the accelerometer, gyrometer, and magnetometer, will only allow certain numbers that are taken as scenarios of car theft and car damage while ignoring minor instances or false positives. If the data given to these conditions are either following the given circumstances or do not, the different pathways will be given to the data being processed, hence why this data flowchart represents how the data flow is controlled.

Sensor Conditions:

The sensors of the SSDC device includes the accelerometer, gyrometer, magnetometer, and CO monitor chips. The accelerometer, gyrometer, and magnetometer will detect motions occurring on the vehicle and process if the data evaluated counts as a car theft and car damage, while the CO monitor will detect levels of CO gases accumulating within the vehicle.

The accelerometer, gyrometer, and magnetometer process the motion of the user's vehicle with the SSDC device differently. The accelerometer detects acceleration forces, the gyrometer, detects angular velocities, and the magnetometer detects the direction of the vehicle. The code will constantly read the measurements from these sensors and process if a car theft and car damage have occurred or to ignore the motion detection. The data that does count as car theft and car damage will be sent to the user through the server and to the user to alert the user that their vehicle has either been damaged or stolen from. The conditions will most likely be complex as the there are a lot of scenarios that need to be accounted for as it requires three sensors and the data required for the conditions to be viable for car theft and car damage can either be one individual sensor or a combination of sensors. The conditions must also take into account the data from the three axes, the X-, Y-, and Z-axis, as well.

The CO monitor detects CO gas levels inside the vehicle from the SSDC device. If the gas levels measured from the CO monitor are excessive, then an alert will be sent through the server to the user. This will notify the user that their vehicle has accumulated excessive amounts of CO that are considered toxic.

(Note: The CO monitor might not be included for the final design of the SSDC device as it is bulky and expensive, which will impede on the requirement specifications and create more constraints when designing the device in further development. This portion of the data flowchart might be removed as well as not provided or ignored when implemented into the code.)

WiFi Conditions:

In order for the SSDC device to connect to the user's mobile application, it requires WiFi connection. The code will check if WiFi connection is provided for the SSDC device can connect to the server. If the WiFi connection is not available, the cellular data will be used to connect to server, which is another way to connect the SSDC device to the user's mobile application, either with LTE, 4G, and 3G. This will require a WiFi chip with the SSDC device to connect to the user's mobile application. The WiFi connection will be used to transmit any recorded live footage, images, and alerts and notifications from the device to the user as well as connect to a server.

Alert Conditions:

The server will send alerts and notifications included with recorded footage and images to the user once the SSDC device is triggered. There will be a condition that processes if the server is transmitting and alerts that car theft and car damage has occurred to the user's vehicle. If this occurs, then the data being transmitted will be processed to the user's mobile application. If not, then the server will be ongoing until an alert has been sent to it. These conditions will also require the type of alert that is occurring and any recorded footage and images to be transmitted to the user's mobile application to reach the requirement specifications and intended functions of the SSDC device to have evidence of the car theft and car damage occurring to the user's vehicle.

Once the mobile application receives the notifications, then it will proceed will storing the recorded footage and images transmitted to the user's cloud storage in their mobile device Just like the conditions for transmitting the alerts from the server, this requires that recorded footage and images were received by the user. This will allow the user to respond to this output when their vehicle is being stolen from or being damaged. This also stored previously recorded footage into the SSDC device once the footage is received.

Storage Conditions:

The storage of the recorded footage and images requires that a mobile device is available from the user. This condition is made in order to ensure that a Cloud storage is provided that is included with the mobile device. If a mobile device is not provided by the user when storing the recorded footage and images, then a error will occur. This error does not necessarily mean that the user's mobile application will stop functioning but will rather let the user know that either a proper mobile device is not available or storage is not possible as Cloud is not provided for storage. This condition is required as to ensure that the recorded footage and images is actually stored somewhere for the user.

(Note: There will be multiple ways to experiment and implement conditions to check if a storage or mobile device is available and ways to respond to this condition as well. This will be looked into more during testing and when the code is being changed when finishing the design of the SSDC.)

User Input Conditions:

The user input conditions are basically the basic functions that the user has on the mobile application and check if the user is trying to access this certain function. This is better explained with the Use Cases Diagram and UI Diagram. The user can view live footage or view the GPS location of the SSDC device and their vehicle. The live footage requires the SSDC device to be active and grant the user access to the cameras to view the inside and outside of the user's vehicle. The GPS locator allows the user to view the location of the vehicle through means of data sending the latitude and longitude of the SSDC device. This chip will be provided in the SSDC device and the user from the mobile application can access the GPS locator to the SSDC device.

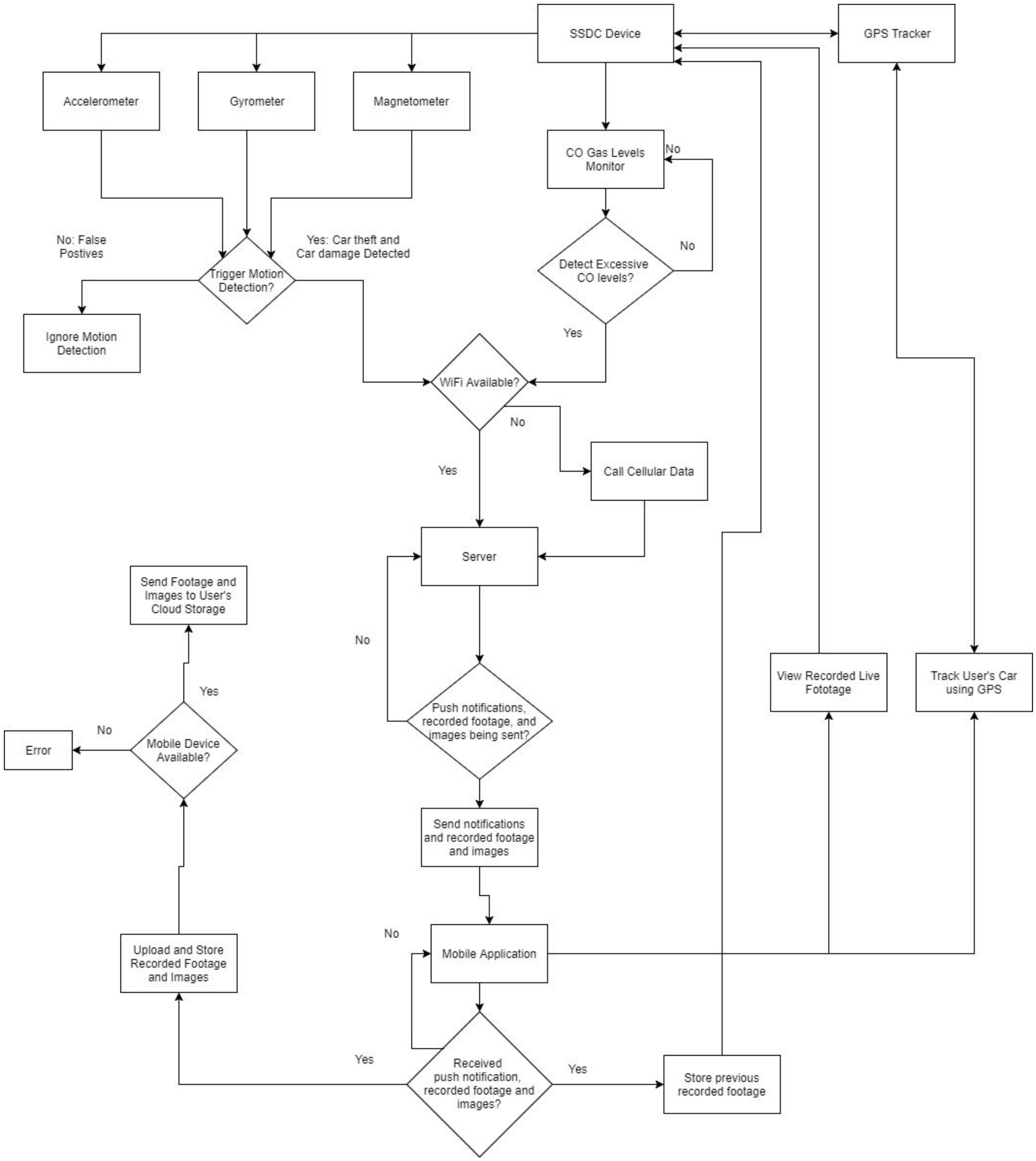


Figure 28: Data Flowchart depicting the SSDC Software Design

Use Cases Diagram

The use cases diagrams shown below is to show the interactions between the user and the server and the server and the SSDC device as well as representing basic functions. The uses cases shown below are to identify, clarify, and organize the basic requirements in the SSDC device. The first use case diagram represents the interactions in the mobile application and the second first use case diagram represents the interactions in the SSDC device.

Mobile Application:

This use case diagram shows the interaction between the user, server, and the cloud storage. The user has basic functions of logging in, viewing the main menu, receiving and viewing notifications, viewing the live footage, and viewing the GPS Locator. Logging and viewing the main menu is a basic function and essential for the user to input their login information for security and the main menu to gain access to the other functions as well. Receiving notification and viewing the live footage, images, and GPS location of the user's device and vehicle requires the server transmit the data to the user.

The server is responsible for transmitting the notifications with the recorded footage and images of the car theft and car damage, the live recording footage, and the GPS location to the user. The server is also responsible for storing the recorded footage and images to the user's cloud storage as well, depending if the mobile device along with cloud storage is provided by the user while using the mobile application.

SSDC Device:

This use diagram shows the interaction between the server and the SSDC device. The SSDC device will be responsible for detecting the scenarios of car theft and car damage as well as providing the live footage, images, and GPS location to the server. The motion detection by the SSDC device will be done with the accelerometer, gyrometer, and magnetometer sensor within the hardware, while the software will filter out any false positives and have it clarify the data if it counts as scenarios of car theft and car damage. The processed data will be used to trigger the device to send the recorded footage and images of the car theft and car damage to the server. The GPS locator will be used to get the location of the device alongside the vehicle it is in. The location will be send to the server as well when the user requests it.

The server will receiving the GPS location and the recorded footage and images to send to the user. The server acts as a transmitter between the user and the device to send the requested GPS footage and live footage as well as send alerts as well.

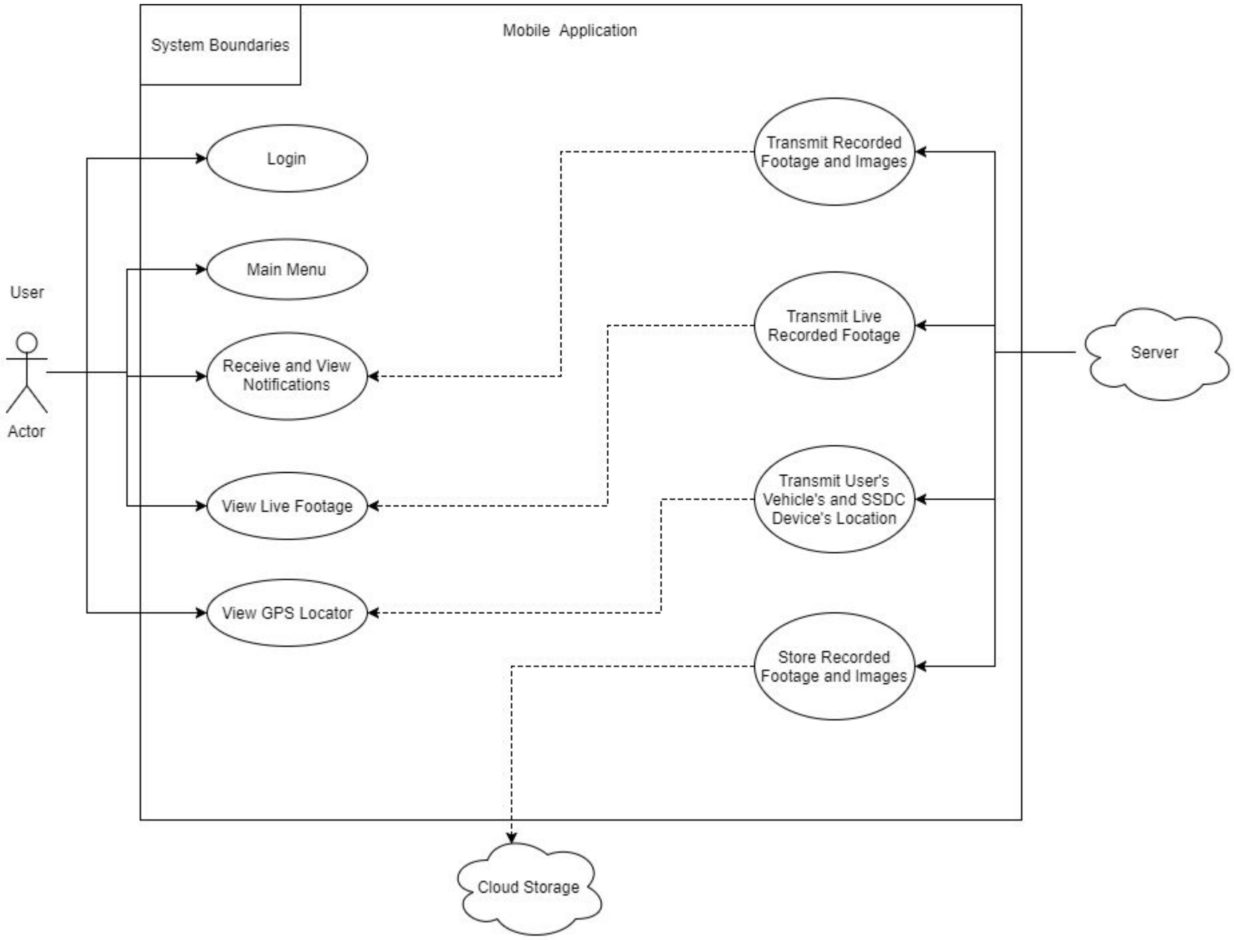


Figure 29: Use Case Diagram for the SSDC's mobile application

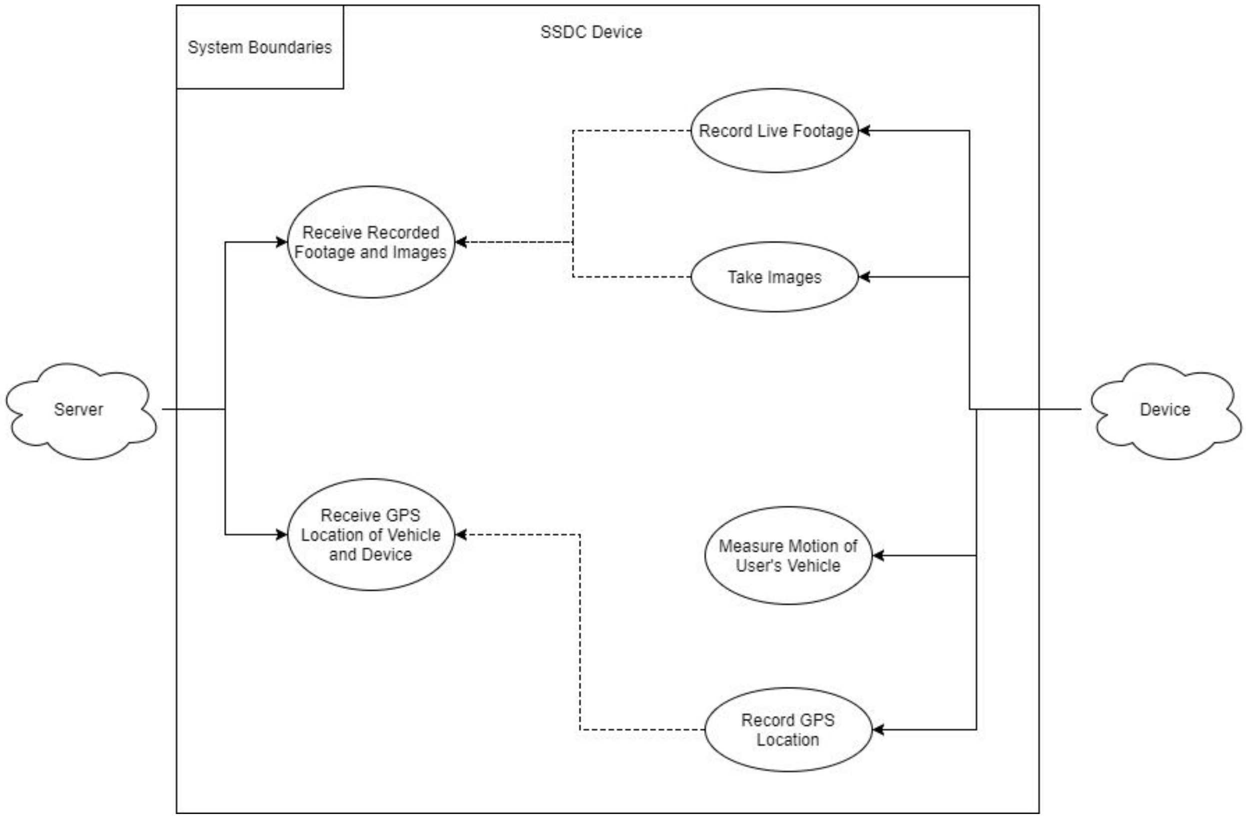


Figure 30: Use Case Diagram for the SSDC Device

UI Diagram

The user interface diagram is used to model the interactions between the user and the interface of the mobile application. Much of the interactions in the mobile application are represented by the use cases diagram where it shows the basic functions of the user, but the UI diagram classifies the inputs and outputs from the user and other objects that are interacting with each other in the mobile application.

User Inputs and Outputs:

The user commands represents the inputs that the user makes on the mobile application or its UI. One input command is to login using the UI with their login information. The login information is stored into the server, so once the user enters the login information it is processed in the server for clarity and security. If the login information is valid, the the user has access to the rest of the functions of the mobile application. If the login information was invalid, the the UI responds that the login information was invalid and ask the user to input their login information again.

The other inputs commands is viewing the live footage and GPS location of the device. The user when interacting with UI to view the footage and location is inputted to the server to gain access. The server then outputs to the user the live footage and the GPS location as well as a response to the users commands.

Server Inputs and Outputs:

The server in response to the user's inputs to view the live recording footage and GPS location by providing access to the data. It will also respond to the SSDC device's inputs as well. When the SSDC device is triggered and sends the recorded footage and images of the car theft and car damage to the server, it responds by outputting the given data to the user interface and the user is able to view the information. The server will also respond by storing the recorded footage and images to the Cloud storage of the user's mobile device, granted it is provided. Live footage and GPS location will be outputted by the user once the user has inputted that they want to view the data as well.

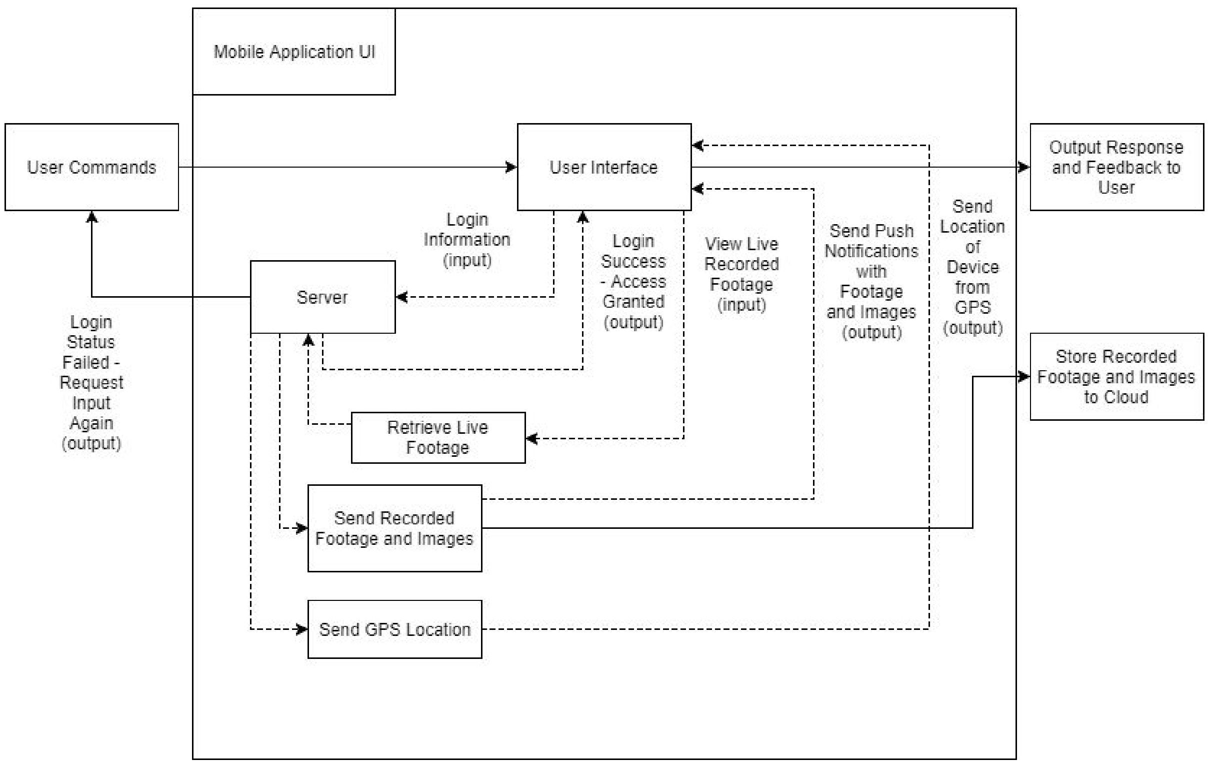


Figure 31: User Interface Diagram of the Mobile Application

ERD Database Design

The entity-relationship diagram represents the entities and their relationships in the database, showing how data is stored, shared, and related to each entity. The entities represented here include the account, device, alerts, sensors, and sessions. For the SSDC device not all data needs to be stored, but there are essential data that will need to be stored such as the accelerometer data and GPS location and the user login information as well. Primary keys of unique identification are provided for each entity are stored to prevent redundant data from occurring and allow the entities to be unique and be distinguished from each other.

Account Entity:

The account entity acts as a storage for the user's login information as well as personal information, such as their name, and, optionally, their address and preferred language. The login information is mandatory to provide security for the user's account as well as provide the user to gain access to their own SSDC device. Their full name will also be filled out as well to identify the user outside of their login information. The address and language will be optional for the user, but the language will automatically be English when viewing the UI.

(Note: The development of the mobile application doesn't plan on providing multiple language setups. The default setup will be English as it is the language that every developer is working with. This also the reason why the language is optional as of making this diagram.ikii)

Device Entity:

Since multiple devices can be used for the same application and user account information as well, the information used to distinguish the device and the user must be stored to create unique connections between the user's device and their mobile application's account information. The device will store info such as its name and the functions as well provided in the UI and software itself. It is also in relation to its alerts, sensors, and sessions, all of which are information that are shared with the user in their account.

Alert Entity:

The alert entity will store the time, title, and type of alert to be sent to the device and as a results will be viewed by the user. These need to be stored as to keep a history of past alert signals of either car theft or car damage to the user. This is also necessary to provide evidence of submission of recorded footage and images given to the user when these alerts were sent.

Sensor Entity:

The sensor entity includes information about the GPS location and accelerometer data that will be provided to the device and stored. It is not necessary to store the gyrometer and magnetometer data as it is not required by the SSDC device's requirement specifications. Also, the information about the accelerometer data and GPS location is more important that the other components for storage. WIth the GPS location, it not only locates the user's vehicle with the device but also where the occurrences of car theft and car damage occur. Recording of the acceleration forces are also needed to identify car damage or minor instances as well as important to recorded the amount of damage caused due to a certain amount of acceleration force.

Session Entity:

The session entity is used to store the user interaction with the device and its interaction with the server as either active or inactive. This is used to keep track of when the user is interacting or using the device. This is also needed for the user to be granted access to the functions of the mobile application as well as be notified and view the live footage, images, and GPS location of their vehicle.

Figure 32: ERD of the SSDC Database

Class Diagram

The class diagram shown below is to represent the objects and their attributes and methods. The class diagram is used to show the data that is stored for each object and the functions that they need to produce. The class diagram takes functions from the data flowchart, use cases diagram, and ERD, but also further shows the data and their datatypes and the names of the methods that will be used to perform the functions for the SSDC device and mobile application. Just like the ERD, the IDs given for each object will prevent redundant data and provide uniqueness for the objects.

User Class:

The user class, as mentioned in the ERD, contains the user's login information in the form of a username and password, which is used for security and gives the user access to the mobile application by using this information. The methods are to allow the user to login to their account a s well as change their account information if they want to change it for security purposes or personal preferences.

Main Menu Class:

The Main Menu is the object used to represent the UI of the mobile application and gives the user access to the mobile application's functions once they are logged in. The user will be able to configure settings, setup WiFi connection, activate the device, and view the recorded live footage and GPS location. Viewing the recorded live footage and GPS location will require the user to interact withe main menu and send an input to the server to gain access to the live footage and GPS location, which is stored in the SSDC device. From the Main Menu, the user will receive notifications and be able to view the recorded footage and images of instances of car theft and car damage occurring on their vehicle.

Server Class:

The server class act as the receiving end of the SSDC device where it will retrieve the device's data and any notifications that will be sent to the user. Before these methods can become active, a connection between the mobile application and the SSDC device must be made so that responses can be made between the two objects. The server will contain a name to identify it outside of its ID. The server will only retrieve the device's data and notification once the device has been triggered and they have been transmitted.

SSDC Device:

The SSDC device will contain all the sensor data, recorded live footage, and GPS Location within the object. With this, the object is responsible of retrieving data from the sensor, live footage, and GPS to be sent to the server so that the user can retrieve the data. This is also where the device will be triggered by the sensor to send alerts along with the footage and images of the instance of any car theft and car damage. The device will also respond to user inputs sent from the server to view any live footage or the GPS location from the device.

- *Sensor Class*: Includes data from the accelerometer, gyrometer, and magnetometer. Responsible for triggering under certain conditions that count as a scenario of car theft or car damage, and as a result will retrieve the data from each sensor and send it to the device to start sending alerts to the mobile application.

    - *Accelerometer*: Contains data of acceleration forces in the X-, Y-, and Z- axis and sends them to the Sensor class to clarify if the scenario is a case of car theft or car damage or ignore it as it is a false positive.

    - *Gyrometer*: Contains data of angular velocities in the X-, Y-, and Z- axis and sends them to the Sensor class to clarify if the scenario is a case of car theft or car damage or ignore it as it is a false positive.

    - *Magnetometer*: Contains data of direction in the X-, Y-, and Z- axis and sends them to the Sensor class to clarify if the scenario is a case of car theft or car damage or ignore it as it is a false positive.

- *Live Video Class*: Contains the recorded live footage from the SSDC device. Once The device sends a response that trigger has occurred then it will transmit the recent recorded footage and take images to be sent to the user through the device and server. It will also respond to any user inputs from the server and device class if they need to view the live footage.

- *GPS Locator Class*: Contains the GPS location in terms of latitude and longitude. The class will respond to any user inputs if they need to view the current GPS location of the device and their vehicle. This will then transmit the GPS location to the user through the device and server for the user to retrieve the information.

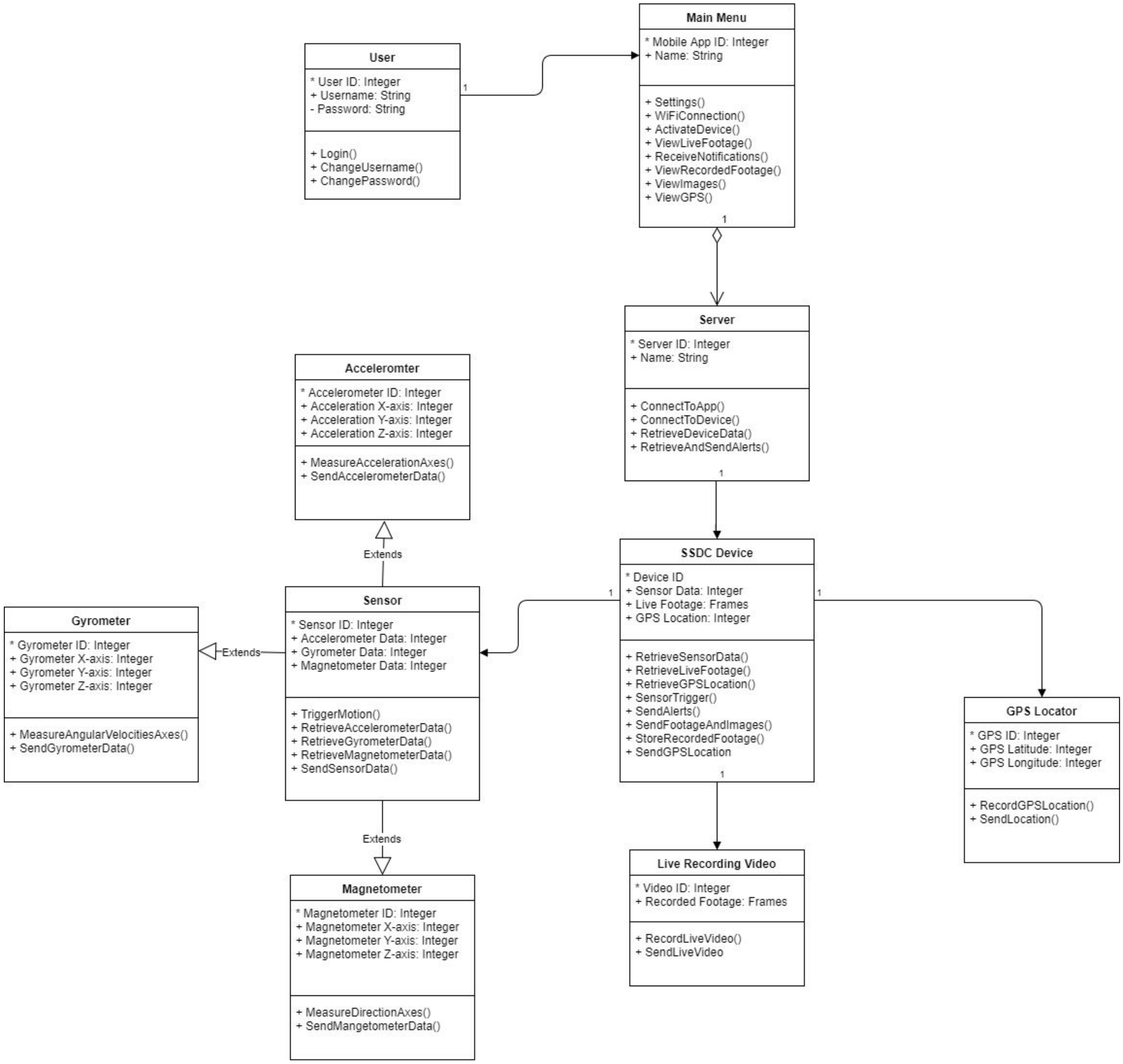


Figure 33: Class Diagram of SSDC Device and Mobile Application

5.2.5 Mobile Application Features

The following sections discuss the numerous critical features and components of the mobile application, this includes detailed technical information, design choices as well as general utilization of the application. All related specifics and challenges will also be discussed in the following sections, little to no specific code will be detailed. The application can be broken into multiple different features that make up the bulk of the application, features such as the live video camera feed, the GPS location as well as the cloud interfacing for long-term accessible storage and synchronization.

Any feature listed below are deemed as necessary features to the critical utilization of the product and are thus prioritized in the development phase. The list below is not representative of all possible features for the product nor is it comprehensive. Any new features or minor additions will be documented at a later date.

Authentication

The mobile application will need a form of authentication and device registration in order to ensure only the correct users utilize the mobile application. It would be a large issue to allow for any user to be able to access the user’s data, control the device or view the live stream. There are numerous safe methods to implement such a feature, many devices will do one time-registrations where you need the device’s serial number or another long hardware unique number associated with the device. It is also possible to force an initial registration that associates the client’s device when the physical device is booted up for the first time, this would make it difficult to utilize other devices to view the feed. Whichever method utilized will require the device to associate itself with a unique identifier or physical interaction with the device to ensure device registration associates the correct device and prevents unwarranted users from registering devices to their phones.

Our device will require a one-time setup on device boot-up that will allow you to connect to the device through the mobile application by simply joining the devices network. Once connected it will pull that unique identifier information and the mobile application will remember and pull the devices connection information, this will include a unique number associated with the device, the wireless password utilized to connect to the device as well as any information related to the settings of the device. The application takes all this data as for the one time registration it will utilize all the information pulled and any data inputted to automatically create a user registration. The mobile application will then utilize the cellular device to send the registration information directly to the registration server.

Once the mobile application has performed the initial registration the user will be prompted to login in order to access the data from the communication server. Registration will only be prompted when requested else a login prompt appears on the mobile application home screen unless already authenticated. Authentication is required in order to ensure that the device is communicating to the correct host.

When a new mobile device wants to connect to the device it logs in with the account credentials created during the initial registration. Upon successful authentication verification with the registration server the device receives a unique identifier for the dashboard camera device as well as a session token and all subsequent requests to the control server will contain the unique identifier and the session token for that device. In this setup it would be possible to implement device login auditing as well as device history. The session tokens provided will expire after a set period of time or on logout, when a user logs out the application tells the server to kill the related session. When a sessions is expired or invalid the user will be prompted to login once again to obtain a new session token. The session token is entirely responsible for validating and authenticating the requests to the SSDC device, as will be discussed in the security section if the sensitive information such as passwords or session tokens are hijacked then an attacker may mimic and control the device themselves.

Notifications/Alerting

A crucial aspect of a security device is the timely notification and alerting of critical security events such as break-ins or physical damage. The device must be capable of sending the device alerts and the mobile application must be able to either convey these alerts through SMS or through the mobile application. The prioritized method will be to send an SMS method directly to the primary registered mobile device associated with the unique device, this information would be stored directly on the device. The SMS message would alert the user that the device has an alert, the alert would contain the following information:

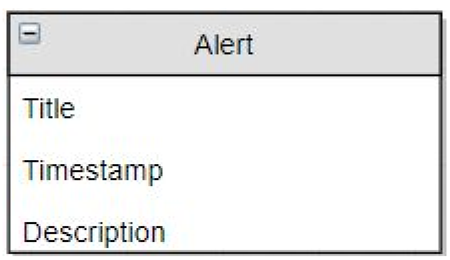


Figure 34: Alert Data Format

This provides sufficient information to the user to alert them to any possible issue, that may have occurred; The user then may check their device remotely utilizing the video feed and determine if an issue is truly occurring. The method at which alerts are determined are discussed later in the paper as the system is critical to the major function of the device. When an alert occurs the device will attempt to send the alert to the server and associate it with the unique device number. Through this method the mobile application will be capable of rendering the alert through the application and even provide a log for all the alerts on a device up to a certain timestamp. With logging a system may be implemented in the long term to allow for the integration of an AI alongside with user feedback on alerts to determine an improved algorithm for determining alert sensitivity.

Video Feed

The video feed involves the live video feed from either of the two onboard cameras of the device. This feature as stated before, will require the mobile application to request the live feed to be transmitted in order to avoid higher than normal data usage. The data when requested will be automatically transferred immediately to the REST server assuming the communication service on the device end is available. If the communication strength is weak and incapable of supporting the full quality of the stream at the preferred 1080p, the device will degrade the service to the maximum possible stream quality available. This may lead to the device only being capable of sending a lower frame rate as well as a lower pixel resolution, the lowest pixel resolution that will be supported being 240p; Incapability to support a 240p pixel resolution will result in the device providing an error stating the lack of service available to the device. Upon error the live stream control will automatically disable the feature to avoid the live stream continuously streaming without the user’s knowledge. The device will of course still saved the data to the local storage for later uploading and ensuring critical information is not lost.

The above figure illustrate the intended UI to be utilized on the Live video interface. The “Live Camera Toggle” button is the control for which camera you are viewing, the button has three states: live feed disabled, camera one feed enabled and camera two feed enabled. Interaction is as simple as toggling through each but may be changed a different UI design, potentially one which will not enable camera one in order to see camera two’s live feed; a potential solution to this problem would be implementation of more buttons, a drop down list design or some other possible more elegant gesture detection control. When the live feed is disabled the live feed will just display a blank error page. The interior enable and exterior enable are also buttons, these buttons provide the ability to disable to the devices cameras during recording. For example during dashcam mode most users may not want their device to record the interior of the vehicle, this will allow for the user to temporarily disable that camera from recording during dashcam mode. The preference will be ignored when the device records due to alerts or live feed.

Video Recording and Storage

The device must be aware of the moments to differentiate between full recording or just taking photos. In order to save power, the SSDC device will only do full video recording when the car is in operation as a Dash Cam and after an alert is triggered or live stream is enabled. The device determines if the vehicle is currently in operation by monitoring the vehicle's battery level, if the car is in operation the vehicle battery should register a higher voltage than under other circumstances. Under these circumstances the device will be constantly recording full video feed to the devices local storage (an SD Card). The device will record all the data that it can until local storage reaches capacity, at which point the device will attempt to upload the data before that point. If the data can not be offloaded by the time which the device reaches a max storage space it will begin to overwrite the oldest data.

If the device experiences an alert the device will also begin to record for a duration of 8 minutes after an alert is triggered. The device will not extend this duration based off any alerts experienced during that time lapse; For example if the device first sees an alert at 10:00 the device will begin recording, the device then experiences another alert at 10:05 before the device has completed the initial trigger recording, at this point the device will end recording at 10:08 as initially determined. If another event is triggered after the the recording is finished it will then begin recording for another 8 minutes. This is to prevent excessive battery drainage from consecutive alerting and to be sure to only record critical events.

If the camera is being operated in the live feed mode the device will begin to record all actively view cameras. As indicated in the above section, the live mode will not activate all cameras only the camera currently being viewed by the user. Whichever camera being activated through this feature will write the device data to storage as possible.

All features may be customizable at some point allowing for the user to customize their recording experiences. Such as in the case if a user would like to downgrade the video quality to reduce bandwidth costs they may be able to adjust the resolution at which the devices record or upload. Another potential setting will be the ability to force the live feed to enable both cameras when live feed is active thus recording through both cameras and allowing for a quicker swap between the live feeds. During the live mode the cameras will power down after a brief period of time of inactivity.

Tracking

The GPS location feature provides the necessary access to track the vehicle through the GPS module onboard the device. The purpose of this feature is to provide a means for finding and tracking the vehicle for purposes of potential theft as well as if the user just mistakenly forgot their vehicle's location. Which can be a handy utility for the user to be able to find their car in massive parking locations such as Walt Disney World. The SSDC device transmits the GPS longitude and latitude of the device periodically along with other sensor information such as the accelerometer and gyrometer to the data server, assuming it has connection and correlates it with the time sent.

The mobile application when swapped to the "Tracking" module of the application will request the last known GPS location of the device from the data server; a button will be available to manually request a sensor refresh to have the device grab more recent information regarding the sensors. Utilizing the grasped information the application will then process the data and formulate it on top of an open source module with an extensive API, most likely google maps as it comes standard on most android devices and is familiar with an extensive open source API for utilization. The user then may double click the location to be provided with navigational options to the coordinates through the use of an external application such as waze or google maps.

Along with the GPS numerous other sensors are available such as the accelerometer and gyrometer. The data associated with these devices are being sent along with the GPS data periodically to the data server. This information while utilized in alerts may not be available to the customer directly. Future utilization may be discovered in repurposing the data for applications beyond alerting such as implementation into a sort of game tracking or statistic analyzer of vehicle speed over time and location. The data may also be utilized after being sent to the server for insurance purposes as well as in a corporate environment driver safe driving checking. The device information has a wide variety of potential uses in the marketing and insurance industries.

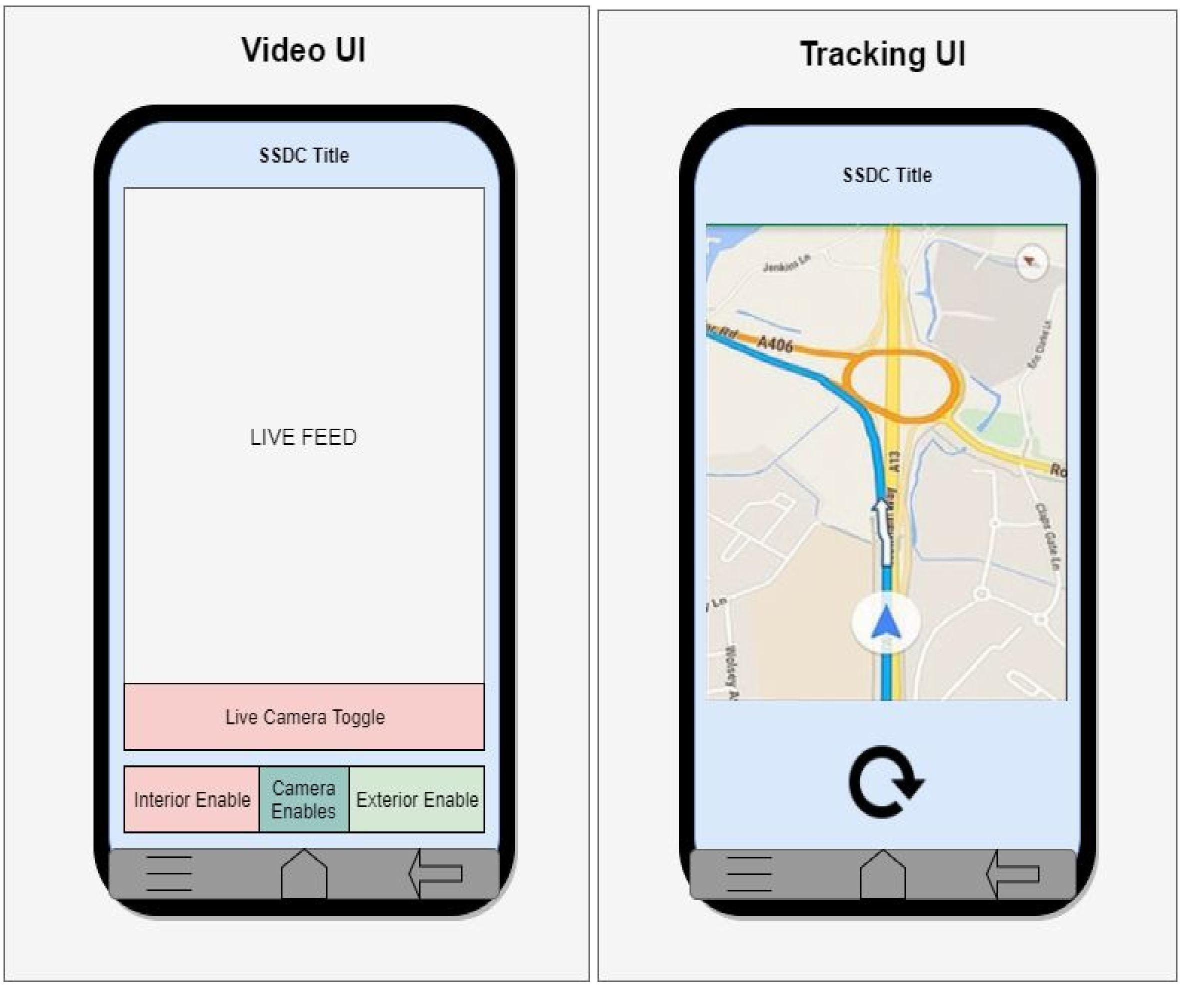


Figure 35: Live Video Recording and Tracking application UI

Settings

The settings menu is valuable to any application to allow for user customization as well account or device changes that are created during the initial device registration. The settings menu will also provide information regarding the device such as that device's serial number, which is a uniquely identifiable number that should be impossible to enumerate. The settings menu will be where the user may customize all the settings regarding the wireless hotspot, the devices known networks, camera and upload settings and other miscellaneous features.

The wireless hotspot settings will provide a diverse group of customizable features. The most important being the configuration of the actual hotspot the user must be able to change the wireless WPA2 key passphrase for the hotspot. Of course the device may have the wireless hotspot renamed beyond the standard default channel of SSDC_{Random Number}. The user from the settings menu may also be able to change security features regarding the device as well as completely enable or disable the hotspot; if the user is connected to the hotspot and then disables the hotspot their communication channel will be ended and the mobile application and device will be forced to swap communication channels.

The wireless connection settings are crucial for the product's operation as the device preferably would desire to be connected to a wireless hotspot over utilization of cellular data, for both bandwidth as well and energy concerns. The device needs to have the feature enabled first and foremost, the user may optionally disable this portion if it may provide battery savings or if is not optimal for their location. User's utilizing the feature must be able to create known trusted networks for the device to connect to as the device will not attempt to connect to random unsecured open wireless networks without the network being added to the configuration. The user from the settings menu may add known networks of either open or secured networks that utilize WEP/WPA/WPA2 to their configuration; a dialog box will appear on the screen when adding new trusted networks that will ask for network configuration such as network SSID, identity, passphrase and connection type. If the user prefers to select the wireless SSID from a menu a dropbox will be available that will force the device to search for visible wireless networks on the 2.4ghz bandwidth , selection will auto-fill the wireless SSID in the menu. From the known networks the user may rank network priority so that the device will communicate with the highest listed priority network over a lower priority network.

The camera upload settings as mentioned in above sections will allow the user to control the program flow of the application and quality of the data and cameras. The user will have the capability to customize the data usage and overall quality of the device. Camera settings may be adjusted to default different features to be enabled beyond the traditional configuration. Settings such as the video quality of the device during recording, live stream and alerting may be changed from up to 1080p the max quality down to 240p; the user will be warned if adjusting the device beyond 720p indicating that the quality will be extremely degraded at that resolution. The camera's may be configured to enable at different times such as implementing the ability to disable the front facing camera while in dashcam mode or enabling the cameras to both record when in live stream mode until the mode is exited. Along with other smaller but enjoyable features that the team deems necessary or marketable.

In order to manage the bandwidth of the device the user may adjust when the device will attempt to offload the videos to the cloud storage. Some users may find they prefer for the device to only upload the video data when the device is connected to wireless over cellular to same data bandwidth costs or that they would like to upload the data at a lower quality than the regular 1080p. While others may find they prioritize the data to be available to the cloud as soon as possible and will have all new recordings be sent to the cloud storage immediately with no care for the communication channel utilized. Other settings may be implemented at a later date for production utilization as well.

5.3 Security

Historically, security has not been a prime issue for new technologies; the coming of internet of things (IoT) devices, smart products that are connected via a form of networking, has brought upon a new dawn of technological issues and risks. Interconnectivity of smart devices and the connection of these devices to the public internet have greatly increased the public attack surface. Security researchers have stated the security risks of IoT devices to be of the highest risk and can be seen by the increase in security research for these devices. According to Gartner Inc, “Worldwide spending on Internet of Things (IoT) security will reach $348 million in 2016, a 23.7 percent increase from 2015 spending of $281.5 million”. The long list of IoT devices increases greatly with every coming year, the issue does not lie solely on the customer but on the poor security implementations of the product designer. These products are being created quickly and mass quantity in order to be the first to market or reduce costs to allow for a higher market penetration. A standard customer may not be aware of the risks of these devices and it may not even be a high priority; Although for devices connected to sensitive infrastructure such as a vehicle, security plays a vital role compared to a smart lightbulb. Depending on the interconnectivity of the device to other infrastructure, the smart device may provide a tunnel to attack devices non-smart devices that are connected to the product. A security product should not introduce security flaws, with this mindset the device has been designed with a complete security mindset.

5.3.1 Attack Surface

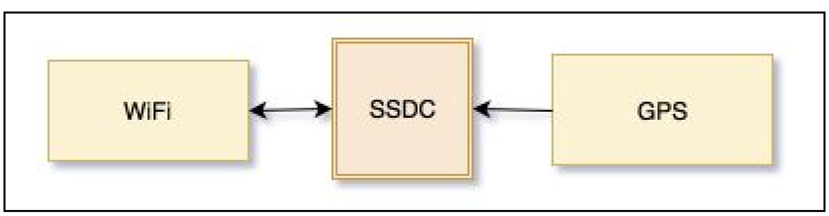


Figure 36: Attack Surface

Attack surface of a device is the possible penetration points for an attacker; Minimizing the attack surface greatly reduces risk and potential access points. In the case of the Smart Security Dash Camera, the device only has three physical potential penetration points: WiFi, the physical device and GPS. The most critical of the three attack points being WiFi, this is due to the remote nature of the technology. Ensuring the security of that attack point will be the most critical to ensure the device and data are not tampered with remotely. The physical device’s security becomes crucial for a physical security mindset. The attack surface of GPS remains only the jamming of the signal preventing tracking. The device as well may be attacked from an application level such as the mobile application and on a network level.

5.3.2 Risks and Concerns

Smart products run the risk of being exploited remotely by attackers due to their level of interconnectivity. The wireless hotspot created by the Smart Security Dashboard Camera provides the ability for an attacker to attempt to perform malicious activities against the device. In the case of a thief attempting to steal the vehicle after noticing the camera, assuming the security of the device was poor, the attacker could simply connect to the wireless access point and disable the device. As well as in the case of remote spying, the attacker upon connecting to the wireless access point would also be able to download all of the data on the device; personal data such as video recordings of the owner in their private property. This has been a concern for numerous smart home devices such as smart security cameras. The SSDC must be designed to ensure the security and safety of the user's personal data and vehicle.

5.3.3 Wi-Fi

Due to the nature of wireless transmissions the data being sent over wireless networks remains completely visible to any receiver decoding the signals. Without encrypting the data any arbitrary individual may receive the transmitted signals travelling the open air and decode the data to understand the transmission. In the case of a standard wireless network not utilizing encryption, an attacker is able to receive all the data packets, including data such as account login information or browsing history. Jamming is another issue with wireless devices, blocking communication from one device to another as is the case with all devices reliant on wireless transmissions.

Encryption for wireless networks (WEP) was first introduced in 1990 and has since been declared insecure, with the introduction of new encryption methods with WPA2 as the current standard. Even utilizing WPA2 a network may still become compromised due to certain attack vectors or weak/insecure encryption keys. The SSDC will require WPA2-PSK implementing a secure password policy.

A secure password policy will be indicated as a key with at minimum eight characters, one symbol, one integer. Although in order to have a stronger security policy users would be encouraged to implement higher entropy keys. Higher entropy can be achieved through a passphrase consisting of two or more unrelated words, this also allows for an easier to remember passphrase.

The device will only connect to wireless networks indicated as trusted by the user, this is to ensure arbitrary unsecured networks are not joined providing an access point for an attacker to communicate with the device. As an attacker may only see the device on a network level by being on the same network as the device. Trusting only residential, work and school networks are recommended to ensure the device is segmented from potentially malicious users.

5.3.4 WPA2-PSK Cracking

Potential for vulnerability lies in the methodology for sharing the the public key in the four way handshake. When the client attempts to authenticated to the wireless access point the client and server utilize this handshake to authenticate the user the access point (AP). The wireless access points security-phrase, more commonly known as the wireless password has to be shared. The client does not send this phrase in plaintext but it is possible to still decrypt the security phrase sent to the access point..

Methodology

In order to capture the handshake packets being sent to the access point we must first have the ability to the run a wireless network card in promiscuous mode to receive all packets that are being sent over the air, even ones not directed to our host. The utilization of a networking security tool, “airmon-ng” and “airodump-ng” are necessary to streamline the process. Utilizing this tool you may monitor all the frames being sent to all SSIDs and narrow down to a specific network. In order to capture the four way handshake a valid connection to the access point has to be made by a client with the correct password this may be achieved with time or by forcing a user to reconnect; to force a user to reconnect may be possible through the utilization of network deauth. This requires sending de-authentication frames to the network to deauthenticate a client. Once the handshake is captured the user may utilize a program to such as WPAcrack to run an attack against the WPA2 password in attempt to crack the hash to the plaintext password.

Risks

The average computer may be capable of testing 3 million passwords a day, thus taking a long time to break the security key. Assuming strong password requirements the feasibility of said attack is low in the volatility of the network and the value of performing an attack. Bruteforcing attacks in known good encryption schemes are typically extremely slow and unutilized in security attacks.

5.3.5 KRACK

The key reinstallation attacks (KRACKS) vulnerability was released to the public October 2017, demonstrating a security flow in the widely utilized WPA2 wireless network encryption standard. The attack tricks the victim into reinstalling the key utilized for network transmission in message three of the four part handshake; accomplished by manipulating and replaying cryptographic handshake messages. The access point will retransmit message three if it detects there was an error with receival, in order to force the client to reset their encryption key the attack just has to replay message three of the handshake. Due to the resets the encryption protocol can be attacked, packets will be able to be forged and replayed.

Risks

Due to the recent release and easy of exploitation the vulnerability risk is higher than would be typically warranted. Release patches have not been provided for all devices, the client side requires the patch instead of the access point. Assuming devices are patched to not reuse the encryption key then their is no risk to exploitation. The SSDC device may not be configured to assist in the prevention of this attack.

5.3.6 SSL

All of the devices data (recordings, statistics and alerts) will be sent over wireless networks. Network protocols by default do not enforce encryption and thus are capable of being decoded by any application with access to the packets. In order to ensure the security of the data being sent to and from the SSDC encryption on the transport layer must be enforced. This may be accomplished by the implementation of Secure Socket Layer (SSL) on the HyperText Transfer Protocol (HTTP) packets being sent over the network. SSL is a protocol built on top of HTTP to allow for secure communications over computer networks.

SSL provides this security through the utilization of a private key and a public key. The public key being the SSL certificate and the private key being stored on the web server. The device communicating to the server may not send and receive data from the web server encrypted by utilizing the keys to encrypt and decrypt messages. There are cryptographically weak algorithms that must be avoided to ensure the messages may not still be decrypted through methods of Brute Force or hashing collisions.

SSDC will implement SSL on all networks utilizing the OWASP best practices for Transport Layer Security (TLS). This will ensure that the data being sent over the networks may not be received and decoded by arbitrary users.

5.3.7 GPS Security

Global positioning system has very little security concerns when regarding the SSDC; As GPS can not be considering a critical system for this product. The utilization of GPS in the system is to confirm your vehicle's position, this may be useful for situations such as towed vehicle or vehicle theft. In the case of vehicle theft, the thief may dispose of the device or if that is not possible jam the device. Jamming the device while uncommon must still be considered as a potential attack method. As such the SSDC will not protect against GPS jamming due to the minimal risk.

5.3.8 Mobile Application Security

A standard attack vector lies in the mobile application. The SSDC will require the utilization of the mobile application to communicate with the device over a secure channel. In order to ensure the correct user is accessing the device the product will also require a secret key; A secret key is a pre-shared key known by the device to be utilized as a form of basic authentication. This key will be provided by the device during product registration and must be entered into the mobile application to ensure only valid users may access the mobile application. The key will follow be randomly generated of twenty-four characters in length, consisting of both numbers and characters.

5.3.9 Physical Device Security

A crucial aspect of the device in order to prevent tampering and theft is the physical security of the device. The device needs to be constructed securely enough to prevent an attacker from removing the device with extreme ease. This can be accomplished by designing all components to be securely built and enforce a locking mechanism to remove devices such as the SD card. This can be achieved by placing the relevant slots near such as the SD card facing a non accessible surface such as the mirror or mount point. Then force a lock on the mount point to ensure the device can only be removed by extreme force or the appropriate user. This will be crucial in ensuring the integrity of the media and device, which will be important in commercial sales of the device. The device may not be completely secured from an attacker as brute force will always provide a means for the removal of the device. The purpose of these counter measures to attack are merely preventive. During the potential attack on the vehicle the camera should be secure enough to cause the attacker to have to stay a prolonged amount of time to allow for both the user to get a notification of the attack as well as bring attention to the attack due to extended duration of brute force.

While the desire of the device’s construction is to create a secure device that is hard to tamper with the future desire of the product is to include customizability. This customizable nature will be in the form of color changes. While this will draw attention to the SSDC it will ultimately serve as a double edged sword. Possible thieves will see the device if it is colored pink or a bright color, but as a result the thief will know the danger of trying to assault a car armed with a security system. It is also expected that the ability to choose colors for the SSDC will increase sales in market by appealing to a vaster amount of users desires.

6.0 Project Prototype Construction

6.1 Hardware Overview

The following section cover the parts chosen to be in the SSDC. The individual parts were explained in prior sections, so this section will list the parts we will use but not all of their specifications. The parts mentioned here will be the parts in the figures and blocks below.

3 in 1 accelerometer, gyroscope, and magnetometer LSM9DS0 - The LSM9DS0 was chosen for the accelerometer, gyroscope, and magnetometer due to its ability to function as all three at the same time as well as having a reasonable price point. The LSM9DS0 boasts testing ranges from ±2 to ±16 g linear acceleration detection for the accelerometer. Its readings range for flux range from ±2 to ±12, and also has a ±245 to ±2000 dps angular rate. The use of the LSM9DS0 removes the need for extra components as well as saves space on the PCB board saving money. The system required input voltage of 2.4v to 3.6v falls within ideal ranges to be able to utilize the 3.3v voltage plane that will be implemented in the PCB. The device will be fully utilized due to the need for every part of the component in the SSDC.

Switching Regulator LM2592HV - The SSDC will run off of a car battery, so the input voltage has to be reduced to a usable level. Fortunately the voltages for the component of the SSDC are for the most part either 3v or 5v dependant. To reduce the voltage to a safe the LM2592HV was chosen to reduce the high input voltage to a stable 5V DC voltage input into a lower DC voltage with a 2ma stable current. A second LM2592HV 3.3V switching regulator will be used to run a physically separated part of the layer to allows the components above to have their voltage supplied from the plane rather that having a vast number of traces. To do this on the PCB it is a simple process of adding a separation in the plane during the eagle creation, and will be translated to the PCB manufacturer through the gerber files.

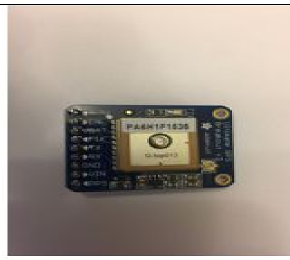
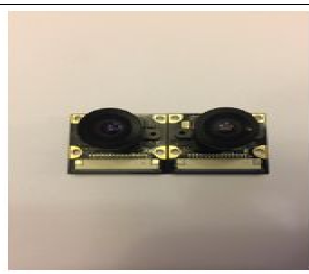
WIFI Chip CC3120MOD - The wifi component selected for the SSDC is the CC3120MOD. Similar to the other components the input voltage is allowable for between 2.7v to 3.7v which falls in the range of the 3.3v. The wifi chip is also low power which is ideal for the low power setting when vehicle is idle. The chip also integrates many of the necessary functions and protocols reducing the need for extra of software programing. The chip also comes with an accompanying arm processor to assist in data transfer and receiving. This reduces the strain the chip will put on the MCU which has to already handle two HD cameras. Also the chip comes with 256 bit encryption which is covered in depth in the security section of the paper.

MCU TMS570LS3137 - The TMS570LS3137 was chosen for the processor in the SSDC due its high performance, already being automotive grade, and falling into other necessary requirements. The MCU requires an input voltage of 3.3v similar to the other components to simplify PCB design. The MCU was also chosen for its dual core running CPUs, memory storage/processing with 3MB of program flash and 256KB of RAM, and an acceptable input bandwidth of up to 186MHz. These were important considerations when choosing this MCU due to the need to run multiple HD cameras. A downside of the MCU is that it cannot run Linux, but it was thought that including a processor that could would result in over engineering. Also already being automotive grade the MCU is thermally acceptable at -40C to 125C operating temperature. This MCU was chosen for the processing due to its affordable nature, and tremendous power for its size, and not knowing 100% a less tested component would fail.

GPS FGPMMOPA6H - The gps chip selected for the device is the FGPMMOPA6H. This chip is a high precision gps chip that is both low power as well as high velocity compatible. The sensitivity of the device is up to -165 DBm, and utilizes automatic antenna switching functionality. The chip also comes with a 1- PPS timing accuracy allowing for extremely accurate location readings.

CDMA AirPrime HL7588 - The HL7588 was chosen for the CDMA chip chosen for SSDC due to performance and price. The HL7588 is a 4G CDMA chip that will access 3G if 4G is not able to connect. This chip has the most reasonable price for 4G performance. The thermal ranges of the chip are between -40 to 85C, so the device meets the desired thermal standards for the interior of a vehicle. Has a 3 volt input which can be easily obtained with the use of buck regulators or voltage dividers. The development board for the chip is also very cheap compared to other CDMA chips.

Surface Mounted Switching Regulator LM5165-Q1 - The synchronous buck Converter with ultra-low IQ allows the circuit to conveniently connect to low current devices such as video processors, MCU, GPS, and any other lower power device. This will allow all chips to receive the same voltage and current constantly. Obtaining low current for the circuit leads to low power consumption. This method can produce less heat and provide more power savings to the device in a time of low power need. The camera needs to record while the vehicle is off. This allows for the user to gain important photographic evidence of any situation outside the norm. The output voltages of the regulator are conveniently 3.3V and 5V. The lead on the high-side P-channel MOSFET can operate at 100% duty cycle for lowest dropout voltage and does not require a super capacitor or battery for gate drive.

 4G Sierra Wireless HL7588	 LSM9DS0 Accelerometer
 GPS Chip FGPMMOPA6H	 MCU TMS570LS3137
 2-170-degree Raspberry Pi 3 Cams	 CC3120MOD SimpleLink

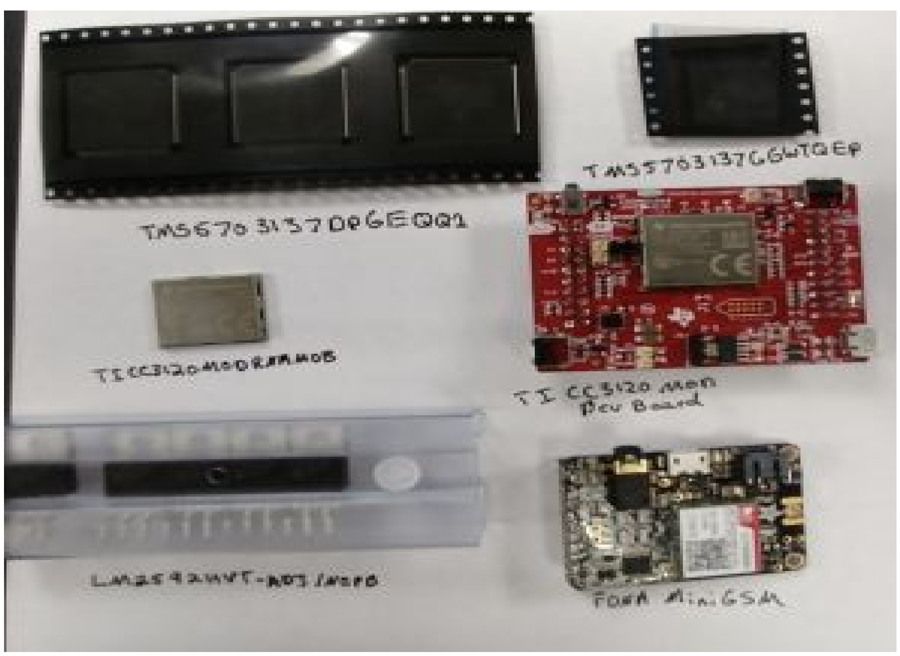


Figure 37: SSDC Device Components and Parts

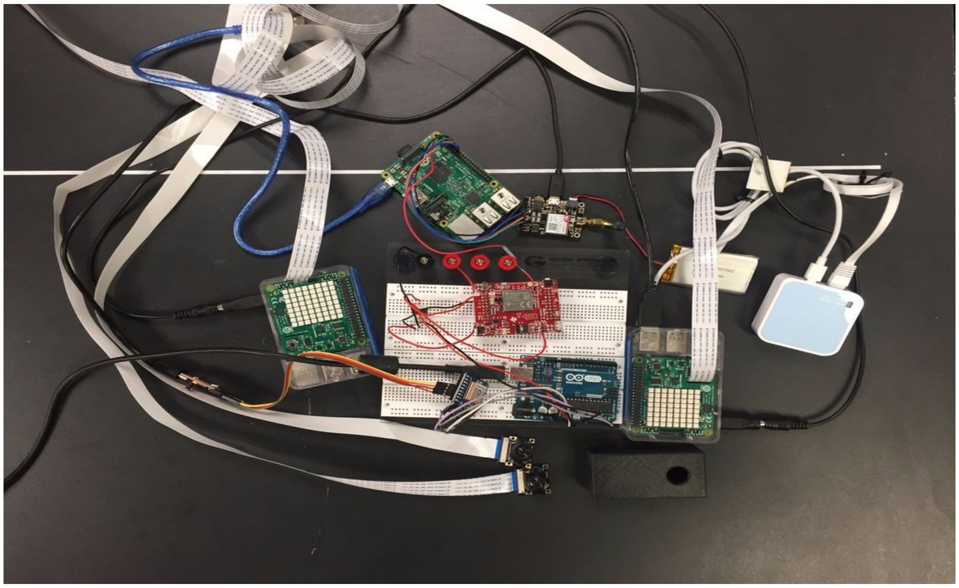


Figure 38: Breadboard Prototype Testing

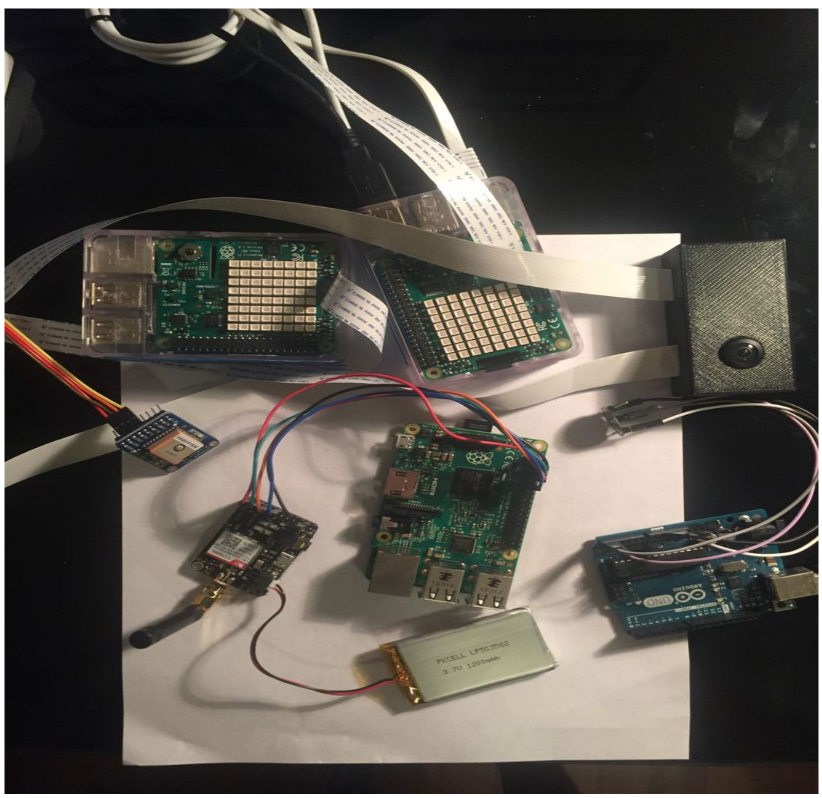


Figure 39: Prototype Testing

6.2 PCB and Integrated Schematic

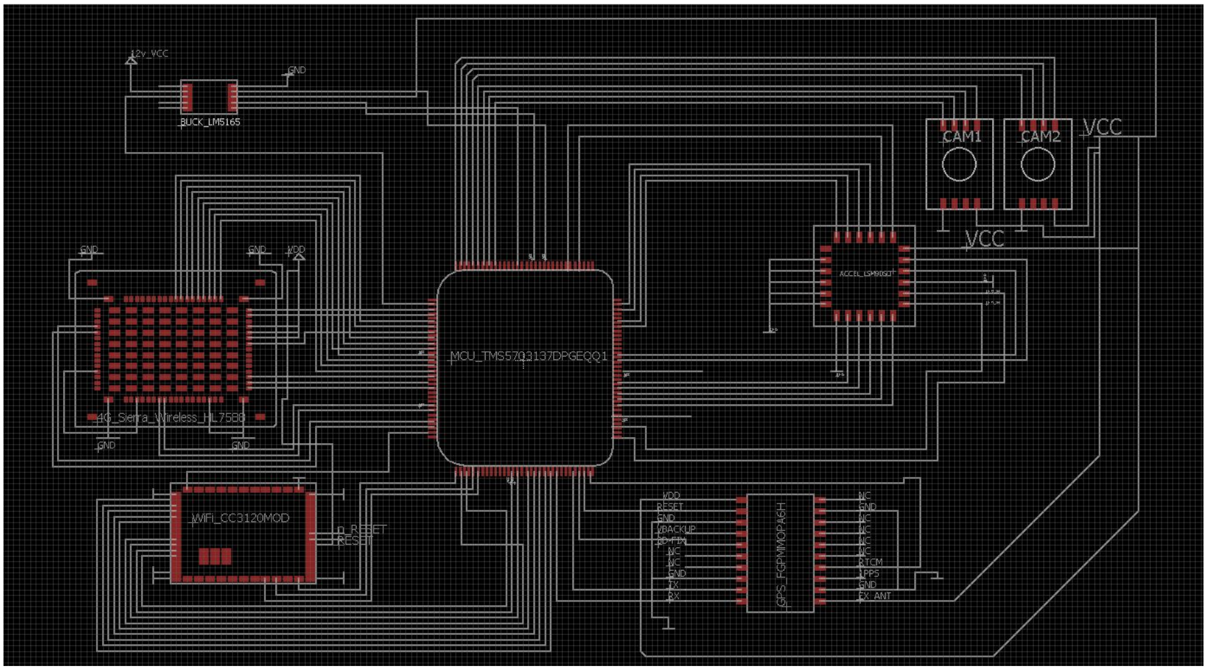


Figure 40: Schematic Design

The above diagram is a draft representation of the schematic design for our PCB board and project. All major components are shown above connected through pinouts determined by the data sheets provided by the manufacturer. This schematic does not demonstrate the final build for the device as it is missing smaller connections such as required resistors, led's and other smaller electronic components required to get the device in a functioning state. Instead the diagram is representative on a higher functioning level than the final schematic.

As can be seen the device stems from the main microcontroller, to all other components. Two cameras lead from the microcontroller to the device connected through 3 singular wires to SPI pins. In the final design these cameras may instead lead to a video processor that then sends the final processed data to either storage or the microcontroller.

From the microcontroller the sierra wireless package as well as the CC3120MOD can be seen connected to the device on the left hand side. These have numerous required connections and will be sent directly to the microcontroller, due to their ability to already process the data on their own chips. In the final PCB design these chips will be positioned on the outside wall of the PCB, obtaining a position as close to the exterior as possible. This is due to the requirement for the devices, they need to be near the external wall separate from parts that may cause interference in order to obtain the best possible signal through their antennas.

On the left hand side of the schematic the power supply conversion for the device may also be seen connected to the MCU. The buck converter provides the power stepping from the received voltage down to a usable 3.3v or 5v power VCC.

On the right side again you can see two more devices the GPS and acceleromater. Both devices which provide analog signals can be seen connected to the device utilizing the onboard analog to digital converter pins in order to read those analog voltages and decode the data. They also fit all of their other required pinouts to the device such as VCC.

The diagram provides a valid representation of the product in the design stage, while some parts are missing such as the low level parts and the SD slot mapping. The final representation will include all such components and be a functioning design of our product that will be sent to the PCB manufacturer of our choosing.

7.0 Project Prototype Testing Plan

The project prototype will need to go through many testing scenarios in order to be validated as functioning properly. Since the project will undergo many possible scenarios that will possibly trigger hardware and software, there are many ways for there to be errors in the design or false positives to be present. Since this is a prototype, the device will not be able to undergo all the possible scenarios if it were placed inside a car and detect car theft and car damage. The prototype device will need to be tested in parking garages, near train stations, and other high vibration environments. This will be done using an arduino with an Adafruit accelerometer, gyrometer, and magnetometer chip. The device will record the different scenarios and use code to make sure to filter them out. This is to ensure that a customer does not receive a false communication error that their car is being broken into. This would make the product non productive as it is only suppose notify the user in parking mode via an a smartphone app if an unexpected theft or crash happens. The other testing will be ensued during normal driving conditions. The camera system should clearly record all of the environment during normal driving conditions during the day or at night. The prototype will also need to be able to upload this video directly to the Cloud storage in real time. This will be done using WiFi and Code Division Multiple Access (CDMA) or Global System For Mobile (GSM) to deliver the data to the cloud in real time. The smartphone app will need to send push notifications to the users and notify of them an event even though their smartphone is on silent.

7.1 Hardware Testing Environment

In this project, the dashboard camera will be attached behind the rearview mirror where most of the hardware will be attached onto the back of the mirror, while the camera portion will be right below the mirror to record footage in front and back of instances that are occurring inside and on the sides of the car and in the front of the car as well. The camera must be able to record clear, live footage in the front and back and have instances where it takes and stores pictures and footage of instances of car theft and car damage. The accelerometer, gyrometer, and magnetometer must trigger properly in order to catch these instances without creating a false positive. The camera will also have to be temperature tolerant, as the car will become extremely hot under harsh sunlight, which can potentially cause the device to malfunction. The camera will also detect excessive emissions of carbon monoxide inside the car as to prevent carbon monoxide poisoning from fumes coming into the car, especially when passengers stay inside the car. The GPS chip is included in case of car theft to detect where the car is currently located.

7.2 Hardware Testing Scenarios

These testing scenarios will mostly test the accelerometer, gyrometer, and magnetometer as they will detect instances of car theft and car damage. The accelerometer will detect instances of acceleration forces, the gyrometer will detect rotation or angular speed, and the magnetometer will detect movement of nearby objects. The camera will be tested in its ability to record clear, continuous footage and be able to record and take images of instances of car theft and car damage. The carbon monoxide chip will be tested in detecting excessive emissions of carbon monoxide present in the car. The GPS chip will be tested in detecting where the car is located when attached.

7.2.1 Accelerometer Readings Test

The accelerometer chip will be wired to the breadboard and connected to a breakout board. The testing will have the accelerometer chip be placed on a dynamic surface, a surface that can move, but also imitate the scenario of being inside a vehicle. Multiple tests of movement and acceleration forces will be enacted upon the accelerometer chip to test its sensitivity and detection of vibrations and acceleration forces.

During and after testing, the accelerometer chip will be recorded on being able to detect vibrations and acceleration forces in the X-, Y-, and Z-axis. The positioning of the 3D plane of the accelerometer chip should be established to distinguish between positive and negative measurements in the acceleration forces. It should be kept in mind that the testing must exclude gravity as an acceleration force during recording as it is constant force that is enacted on the Z-axis of the accelerometer chip. It should also be kept in mind that the detection values will be different when the vehicle is running and when user is driving the vehicle. This type of testing will be done and verified when the design is more compatible when placed inside the user's vehicle.

This testing is done to observe the behavior of the accelerometer chip when vibrations and acceleration forces are enacted upon it and its surrounding environment and also ensure that the accelerometer functions properly, which is to detect acceleration forces. One example of testing the accelerometer on the breadboard and breakout board is to have it wired to its x, y, and z axes and connected to LEDs for each axis to detect any instance of vibration or acceleration force. Test cases will simulate scenarios of car theft and car damage and false positives, such as minor vibrations in the environment or minor acceleration forces that should not be registered as damage to the user's vehicle. These results will be recorded to filter out any instances of false positives and be implemented to the accelerometer chip to trigger the device of actual test cases of car theft and car damage.

The accelerometer chip should be aimed to these objectives at the end of testing:

- The accelerometer should detect vibrations and sudden acceleration forces occurring on the dynamic surface.

- The observed test results should be recorded and used to filter out any false positives.

- The accelerometer chip must be implemented to better detect test case scenarios of car theft and car damage.

- The accelerometer must be able to properly record driving acceleration data for indexing purposes, and drawing correlations.

7.2.2 Gyrometer Readings Test

The gyrometer chip will be wired to the breadboard and connected to a breakout board. The testing will gyrometer chip be placed on a rotating surface to test its sensitivity and detection of rotations and angular velocities. These rotations and angular velocities should be simulated to represent a user’s vehicle.

The gyrometer chip will be recorded on the breadboard and breakout board on the instances that it detects any rotation on the X-, Y-, and Z-axis. An example of this type of testing will involve LEDs being connected to each axis to observe the detections of angular velocities on the rotation surface. These rotation should be simulated to represent pitches, rolls, and yaws. These types of rotations occur on different axes of the gyrometer chip. These rotations should be tested independently and should be distinguished on what type of rotation was enacted on the surface where the gyrometer chip is connected to. It should be established the positioning of the gyrometer’s 3D plane to distinguish between the positive and negative angular velocities occurring on the rotating surface. These recorded results will be used to distinguish between instances of car theft and car damage and false positives.

These results will be implemented to the gyrometer chip to filter out false positives so the gyrometer chip will trigger the device properly. These types of rotation measurements will be different when the user is driving their vehicle as the vehicle will constant turn and rotate. This type of testing will be done when the SSDC device is more compatible with being placed inside of a vehicle.

The gyrometer chip should be aimed to these objectives at the end of testing:

- The gyrometer should detect sudden rotations or angular speeds occurring on the rotating surface.

- The results should identify the different types of rotations occurring on the rotation surface.

- The recorded results during testing should be used to filter out any false positives.

- The gyrometer chip should be implemented to trigger properly during test cases of car theft and car damage.

- The gyrometer chip must accurately record the angular velocities of the device.

7.2.3 Magnetometer Readings Test

The magnetometer chip will be wired to the breadboard and connected to a breakout board. The testing will have the magnetometer chip be placed on a dynamic and rotating surface. The testing done with the chip will be to observe how the magnetometer chip will detect the direction of the user's vehicle as it moves and rotates. This type of movement of the user's vehicle will be simulated on the magnetometer chip to observe its behavior.

The magnetometer chip will have different tests on its position and location by having it turn at different angle, at different heights, and move as well to determine the direction the surface of the device it is attached to and simulated the car being moved in a certain direction. The different type of positioning, location, and directions should be recorded. It should also be recorded on which the 3D plane axes are pointing when the surface is moving in a certain direction to observe the behavior of the magnetometer chip. This will be done by having LEDs connect to the axes to record the direction the surface is going during testing. Verify that the result match the direction of the surface. Then, test case scenarios will be enacted upon the magnetometer chip of car theft and car damage and false positives.

This testing will be done to distinguish the type of recorded directions of the magnetometer chip during these test cases. The recorded results of these test cases will be used to implement the magnetometer chip to filter out false positives and trigger the device during scenarios of car theft and car damage. More testing will be done in the future as these results will be different when the user is driving the vehicle from the simulations made during prototype testing.

The magnetometer chip should be aimed to these objectives at the end of testing:

- The magnetometer should detect the direction the surface is going in during testing simulation.

- The results should identify the different types positioning, locations, and directions.

- The recorded results during testing should be used to filter out any false positives.

- The magnetometer chip should be implemented to trigger properly during test cases of car theft and car damage.

7.2.4 Camera Recording Footage Test

Two cameras with at most 170 degree view (or at least 160 degree view depending on the type of camera lens used) will be used to record instances of car theft and car damage. These cameras will be tested if they can record live footage at 1080p and 60fps. For the sake of prototype testing, the camera footage recorded might be 720p and 30fps depending on the cameras used for the prototype testing, and the team will most likely used different set of cameras if the recorded footage is not clear or efficient enough for recording the footage intended for the SSDC device. These cameras will also be tested on how clear the images it can take when the SSDC is triggered during instances of car theft and car damage. For this type of testing, either the accelerometer, gyrometer, and magnetometer must trigger the device properly for the camera to take footage and images of the instance or simulate the scenario to have the device be triggered.

The two cameras should be place in a position where one covers the back, while the covers the front field of view. This is to simulate how the cameras will be mounted onto the car's rearview mirror in further testing when the SSDC device's design is more compatible for such test case scenarios. This helps get a view of the inside of the user's vehicle and the side mirrors and a view of the front of the car viewing past the front mirror. This will help capture any instances of car theft and car damage in almost full view when the device is triggered. These cameras will be put into different angles and positions to observe the footage and its efficiency.

The cameras will then be tested during triggers in the SSDC device by either the accelerometer, gyrometer, and magnetometer chips or simulated scenarios by having the SSDC device trigger or have the cameras trigger to record the footage and take images. If the accelerometer, magnetometer, and gyrometer chips were used to trigger the cameras and they don't properly trigger the cameras or trigger during false positives, then testing needs to be revisited on those chips and these results need to be recorded if they were successful or not.

The footage and images recorded must be clear enough to view the incident happening in real time. The footage must also be consistent with no drops in quality or frames depending on the camera's parameters and the images taken must have the instances be visible to the user from the camera. The stability of the cameras must be tested as the cameras need to have minimal vibrations in order to record clear footage. The cameras must be tested in different brightnesses as the recorded footage and images must be clear during bright daylight and night time, especially when the device and cameras are triggered. The recorded test results will be recorded to be either a success or failure in the different test cases. The test cases must be distinguished from one another to identify the purpose of the test and for the testers to know if the test was a success or failure for the type of test.

By the end of testing the cameras, it should reach these objectives:

- The two 170 degree cameras should record clear, live footage at all times.
- The footage and images must only be stored when these instances of car theft and car damage occur as storing continuous footage will use too much data.
- The footage and images stored should have a clear visual of the car theft and car damage occurring.
- The cameras must be be kept stable, or be able to not shake when the car is being driven or when the car shakes from its surroundings.
- The cameras must be able to have a good angled view of inside and outside of the car.
- The camera must be able to have a view in different brightnesses, either during bright daylight or nighttime.

(Note: The testing done for the prototype will not reach all of these objectives as the team won't be able to have accurate enough simulations of these scenarios. Also, the cameras used might change as they must be clear enough footage for the SSDC device to function to its requirements. Because of this, more testing must be done with the cameras once the design and functions of the device are more developed.)

7.2.5 GPS Chip Testing

The GPS chip will be connected to a breadboard and breakout boards to test. The GPS chip will need to be powered to be tested. The GPS chip will be tested to observe how reliable it is in transmitting the location of the SSDC device with the GPS chip.

Test cases will involve testing the GPS signal strength in various locations that a car would be, such as a house's garage, surface streets, and multiple parking garages. The signal strength should be a reasonable level such that it would give the location of the module within 2.5 meters. This type of testing will not be accomplished with the prototype as the device will need to be more developed before moving the SSDC device with the chip in multiple locations.

For the prototype testing, the GPS chip will be moved to more reasonable distances where the testers can be able to observe the distance and connectivity immediately. At most, the GPS chip should at least transmit its current location in order for it to function for the prototype. Multiple test cases will be recorded along with the distance from the users and the GPS chip itself, and its signal strength and reliability.

By the end of testing the GPS chip, these objectives should be reached:

- The GPS component should reliably communicate with GPS satellites and transmit location in various scenarios.
- It should also be able connect in a parking garage, to ensure proper functionality in parked vehicles.

(Note: There needs to be further testing as these objective might not be reached. At most, the GPS will be tested to transmit accurate location of the device with the GPS locator during prototype testing. Further testing for farther distances and different bandwidths will be done when the SSDC device's design is more developed.)

7.2.6 Carbon monoxide Monitoring Chip Testing

The carbon monoxide monitoring chip will be connected to the breadboard and breakout board and be powered by a battery or a voltage source. The carbon monoxide chip will be used and tested to detect CO gases that can accumulate in the inside of vehicles.

The device will be placed inside of a sealed container with another carbon monoxide detector with a digital read-out of the PPM of carbon monoxide. Using an aerosol carbon monoxide bottle, spray carbon monoxide inside of the container. The device should alert based on the following table bellow of PPM of carbon monoxide and the amount of time at that level.

Each threshold should be tested independently and reset between each test to ensure no false positives are produced. If any of these thresholds are passed, the device should throw a flag which would allow the controller to notify the user as well as create an audible sound to alert occupants of the vehicle. These test results should be recorded independently as well with the recorded amounts of PPM that has accumulated, the alarm expected and actual response time, and if the test succeeded or failed in alarming the user of the CO levels.

(Note: This type of testing might be simplified to observe if the chip can measure accurate amounts of CO gas levels and if it can trigger properly at the right response time.)

Carbon Monoxide Levels	***Alarm Response Time***
40 PPM	10 Hours
50 PPM	8 Hours
70 PPM	1 Hour
150 PPM	10 Minutes
400 PPM	4 Minutes

Table 11: CO Alarm Response Time Levels (Permission Pending) [25]

By the end of testing the carbon monoxide monitoring chip, these objectives need to be reached:

- The carbon monoxide monitoring alerts the user if unsafe level of carbon monoxide are detected. Either long-term exposure or acute exposure.

(Note: This type of testing will be different in future testing with the carbon monoxide monitoring chip as the scenario of placing it inside of the vehicle might have different levels of CO gases. This should be taken to mind for the prototype testing and must be studied further of the CO gas levels that can potentially accumulate inside a vehicle.)

7.2.7 Temperature Tolerance Testing

The temperature tolerance will be tested to observe if the components can operate and function in the SSDC device at low and high temperatures. Since these components are going to be used inside the user's vehicle, they can potentially can get extremely hot during high temperatures of the day. Each component has parameters and a temperature tolerance range when buying the product. These parameters will be testing within and outside its range to test the components functionality in these temperatures.

Each component listed above will be tested for humidity, heat, cold, and spontaneous temperature change tolerance. These factors will be tested through the use of environmental testing chambers. Testing chambers provide a very high level of control for certain aspects of the testing zone such as humidity. These chambers will be rented for the testing of the product. However, this testing is not a possibility in the time span of senior design, but since the focus of this project is for the creation of a full fledged marketable product which will require thorough testing of the specified conditions. This is due to the environment which the camera will be located will typically be subjected to great fluctuations of heat, cold, and humidity.

For the prototype testing, the components will be tested differently. The components will be placed inside an environmental test chamber capable of reaching low temperatures of -40°C (-40°F) and then they'll be placed inside an environmental test chamber that can reach high temperatures of 85°C (185°F). Once the components reach their targeted equilibrium temperatures, they will be tested to observe if they still function properly for the SSDC device. If it does reach its intended functions, such as recording video footage and sending the video footage to the user's mobile device, as well as the SSDC's GPS location, then it will be considered acceptable to meet the requirement specifications of the SSDC device. These recorded results need to identify the temperature that the component is in and state if the component still functions with this temperature applied. The components will have multiple test cases that are within the range of its parameters to test if it's given parameters are accurate and some test cases outside of its intended temperature range to test its limits.

By the end of the temperature tolerance testing, these objectives should be reached:

- The components should work in ranges from -40°C to 85°C (-40°F to 185°F).
- The circuits should be able to be functional on all temperatures in these ranges, as the temperature in vehicles can vary widely.

(Note: The components used may be replaced for more efficient and functional uses that are related to the requirements for the SSDC device, meaning that the temperature ranges will vary between each product used. The aim for these components is to have a temperature range that will function in the temperatures that can be reached when placed inside the user's vehicle in order to prevent the issues of improper functionality from a temperature limit.)

7.3 Software Testing Environment

The software of the project prototype will be done using Python programming language and be used in an Android mobile application. The interface will be simple and accessible to the user with little learning and effort on how to use the application. The user will be able to view the recording footage live inside the car using the application at all times. The interface will have an internal storage for recorded camera footage and images of instances of car theft and car damage. These instances will be notified to the user's mobile application using push notifications, even though the mobile device is silent. The recorded footage and images will be stored through Cloud storage using WiFi and Code Division Multiple Access (CDMA) or Global System For Mobile (GSM). The interface will provide an instruction manual to provide assistance to the user on how to use the application. The user will have a GPS tracker in their car connected to the mobile application to know the location of the user's car. The mobile application will be connected to the Smart Security Dash Camera (SDCC) through WiFi. The software will be used to filter out instances of false positives to have the controller trigger properly during instances of car theft and car damage.

7.4 Software Testing Scenarios

The software of the project prototype will be tested with multiple triggers from the accelerometer, gyrometer, and magnetometer to distinguish real instances of car theft and car damage and instances of false positives. Observing these instances that trigger the controller will present scenarios that need to be filtered out to have the controller only trigger during real instances. The coding should allow live recording footage at all times and be consistent to be 1080p and 60fps. The mobile application should be coded to allow storage of recorded footage and images during valid triggered instances of the controller. This should be stored exclusively to the user's Cloud storage through WiFi and CDMA or GSM. The coding of the connection between the Android application and the device through WiFi should be tested to observe if there is a strong and efficient connection. The GPS tracker should be tested in the code to observe if the connection functions properly through software.

7.4.1 Data Readings of Accelerometer, Gyrometer, and Magnetometer Testing

Code must be first prepared and implemented for the accelerometer, gyrometer, and magnetometer testing. This code must be designed to trigger the device once the components detect any instances of car theft and car damage. It is also suggested that the code should output any response when the device is triggered for the person on the other end of the code to detect when the code has activated the one of the triggers. Comments and the names of the functions should clearly identify its purpose in the code and which component it is associated to.

(Note: This testing can also be done along with the hardware testing of these components, but the test results should differentiate which results are measuring the hardware and the software during the test cases. Also, if both test cases record instances of the device not triggering properly or trigger during false positives, both hardware and software should be implemented to trigger the device properly. This is to keep consistency with each test case and have the hardware and software be recorded for each change and implementation at the same time.)

Before enacting the test cases, the positioning of the components must be predetermined before determining what the positive and negative values for each component mean. This is for the testers to make sure that the results are accurately measured and the intended scenario matches the results in the right directions and axes. Once the 3D plane position for each position is established, each component should be labeled where the axis is and be recorded during each test case.

When the code is running, it should output the current measurements of each component of the SSDC device. The accelerometer should be measuring acceleration forces, the gyrometer should measure angular velocities, and the magnetometer should the direction of the device in the form of magnetic fields. It should be realized that gravity will affect these components all together. So the code should either ignore the gravitational forces (this might be already done within the components depending on the product), or the gravitational forces should be removed from the recorded results to have more accurate measurements. This will help record the results of the the test case scenario as well as see the change in the measurements as well.

(Note: The environment the device and components are in must be an area where there are little movements are anything that can cause any rapid changes in the measurements or inaccurate results. The previous state of the components must be recorded before the test case scenario begins to observe the change in the measurements. The results should just measure the values that are stored for the results, it should also the changes as well as it is a more accurate measurement to observing the behavior the components.)

Multiple test case scenarios for the prototype will be done to simulate the inside of a car vehicle that is parked. These scenarios will vary from minor vibrations, rotations, positioning and movement for a sense of direction to observe the behavior to extreme cases that can count as car theft and car damage. It should be documented from these scenarios if they're false positives or not. It should also be documented of what type of scenario is trying to trigger which components. For accelerometers, the direction and the probably acceleration force must be identified, for gyrometers, the the of rotation, such as a pitch, roll, or yaw to the different axes at either clockwise or counterclockwise must be identified, and for magnetometers, the direction the chip or device itself is moving must be identified. This is to predetermine what the results should look like in order to verify that the code is take the measurements accurately. If the results do not match the test case scenario, the the test should be redone in order to get more accurate results.

After collecting enough results from the test cases, the gathered information will be used to add any implementations to the code for it to trigger properly during test cases of car theft and car damage while also filtering out any false positives. The test cases should be repeated while also recording the type of test case and the results for further implementation. Each time the developers change the code, it must be documented that the new test cases were done after these changes in order to record the version history and check if the implementations improved the results, introduce more faults, or barely change the results to become more functional and efficient for the design. Enough tests should be done until the developers have decided that they have an idea overall on how the major hardware components will work with the software to develop the device more.

(Note: These test cases will not be completely accurate to real life scenarios as these will be simulations during prototype testing and the components might change for more suitable ones for the SSDC device. Further testing when the design is more developed should document the changes over time with the design and how it has changed while also compared previous test cases to tests cases done on the more developed design of the SSDC device.)

At the end of the data readings testing, these objectives should be reached:

- The code should trigger instances through the accelerometer of car theft and car damage in the controller and filter out any false positives.
- The code should trigger instances through the gyrometer of car theft and car damage in the controller and filter out any false positives.
- The code should trigger instances through the magnetometer of car theft and car damage in the controller and filter out any false positives.
- The code should identify and notify the user of either car theft and car damage occurring.
- Data readings should be recorded before, during, and after testing.
- Any changes or implementations to the code must be recorded along with the data results that come with each implementation of the code.
- Code must still function the same and work more efficient as previous versions and identify and remove any errors and faults that may lead to failures.

(Note: Not all of these objectives will be reached as there will be time and effort constraints with implementing and recording the results in the test cases planned for prototype testing. However, this type of testing can be considered in future testing of the SSDC device when it becomes more developed.)

7.4.2 Received Recording of Live Footage Testing

The code for the recorded live footage should be implemented to observe the behavior of the code running when the live footage is being recorded. It should have an output that tells the tester that the footage is being received on the other end and at any point when the recorded footage goes through any errors, that the tester receives the note that a major error or fault has occurred when the code and test was running.

(Note: This testing should be done along with the recording footage of the two cameras in the hardware testing as the recorded live footage is dependent on the cameras. but the test results should differentiate which results are measuring the hardware and the software during the test cases. When testing both the cameras for recording footage for both the hardware and software, the hardware test should have the cameras be positioned on different angles and locations when the software is running to observe how the code is receiving the recorded live footage when the hardware is changing viewpoints. If any errors or faults occur in the testing, then both hardware and software should be looked into.)

The footage should pass the black and white vertical line test, and be able to differentiate between different colors placed next to each other. This will be to test how the recorded footage will handle different brightnesses when exposed to daylight and nighttime. The camera will then be tested to ensure an almost 360 degree view around the vehicle. This type of testing will be dependent on the cameras as the degree turn is dependent on their parameters. It should be recorded on the maximum angle viewpoint that the recorded footage can achieves when running the code and if the footage is being processed efficiently through the code as the cameras are turning for a new viewpoint.

The camera will record until the storage space is filled to test the consistency of the recording at 1080p and 60fps while it is active in recording footage. The SSDC device or the cameras will be placed in random locations and tested to see if the device can send images to the phone application. Should the area tested not be in range of any cellular towers then the device should start to send data when it becomes in range. The SSDC will be tested to ensure that a remote view of the SSDC can be achieved when the vehicle is within range of WiFi.

(Note: This type of testing might be simplified for the prototype testing to only test its consistency and having the cameras be recorded in accessible areas. Further testing will be done to observe the recorded footage if achieves the requirement specifications when the SSDC device becomes more developed.)

The different test cases must be documented on where the recorded footage is taking place, the conditions it is in, such as the brightness or maximum degree turn, and if it has succeeded or failed any of the tests given to it. The code should be examined as well during these test cases to observe any errors or faults that may occur that can cause failure.

The camera and data will be considered successful if the application can view the camera remotely at 1080p and 60fps. Should the frames be lacking or the view not be in 1080p the camera will need to be analyzed to find the errors in the device causing such abnormalities, and then be fixed/replaced. If the device can not be accessed both the connection quality as well as the device will need checking for errors. The test cases should be done again to observe if the implementations improved the results or have not changed the overall results at all.

(Note: The type of cameras used in the prototype testing might change when the device becomes more developed if it is required to meet the requirement specifications. This should be documented when doing further testing for the recorded live footage. Live footage availability also relies on cell carrier 4G LTE bandwidth in the surrounding area. There may be a slight latency in the video and the video may not appear to be completely 1080p 60fps.

At the end of the testing for the received recorded footage, these objectives should be reached:

- Live footage should be available at all times to the user on 4G.

- The user should be able to view the live footage in real time using the mobile application.

- The live footage should stay consistent in 1080p and 60ps with no drops in the quality of the footage and frames.

7.4.3 Storage of Recorded Footage and Images Testing

Just like the recorded live footage testing, testing should be done along with the recording footage of the two cameras in the hardware testing as the recorded live footage is dependent on the cameras. but the test results should differentiate which results are measuring the hardware and the software during the test cases.

For this testing, the software must be looked into extensively as the storage of the recorded footage and images must be done properly in the code. The live recorded footage from the cameras can be changed for a better viewpoint by changing the positioning and angle of the cameras to view the target in the recorded footage and images. Any abnormalities or errors for the hardware or software of the recorded live footage or cameras themselves must already be looked into and fixed with implementations during the hardware camera testing and the software live recorded footage testing.

The code will be implemented to trigger the camera to record footage and take images of simulations of car theft and car damage when it occurs. This should be triggered by the device's accelerometer, gyrometer, and magnetometer data readings, which should already be verified during its testing for both its hardware and software. If the major components in detecting the acceleration forces, angular velocities, and direction are functioning properly for the SSDC device, then testing for those components in both hardware and software must be looked into again to have the device trigger properly for these tests.

(Note: It is possible to do these tests without having the accelerometer, gyrometer, and magnetometer trigger the cameras to record the footage and take images. Simulated triggers are possible in order to test if the recorded footage and images where properly stored to the user's mobile application. However, it must be documented that the triggers were simulated rather than being caused by the components of the device. Future testing must have the components trigger the device rather than simulated triggers.)

The SSDC should be placed behind the rear-view mirror inside the car and be position in angled in a way that can capture the footage and take images of the car theft or car damage occurring. Since this is prototype testing, this can be done by having the cameras face the front and back to have an almost 360 degree viewpoint. Check if the camera is currently recording footage and can still be seen live on the mobile application. This test should've been verified in the received live recording test.

Enact scenarios that would trigger device of car theft and car damage or cause false positives. If the device is not triggered by a scenario of car theft and car damage or a false positive occurs, then the data readings for the accelerometer, gyrometer, and magnetometer should be looked into again, or if it is a simulated trigger, check the code of where and why the error has occurred. There should be further coding implementation and testing for the cameras to be properly triggered and to filter out any false positives.

When the device is triggered, the user's mobile application should receive a push notification of car theft and car damage occurring in real time and have the recorded live footage and images stored into Cloud. The user should be able to view the recorded footage and images from their Cloud. The user should also have clear view in the footage and images of the car theft and car damage occurring. If the user cannot view the instance happening in the recordings and images, then the camera should be properly positioned and angles again. If the user is not able to view the instance occurring clearly then the device needs to be analyzed for any abnormalities in the recording and be fixed.

(Note: This type of testing will probably be simplified as there will be time and effort constraints when implementing the code to have the mobile application have a push notification. The testers may use a simple output result relying whether or not that the device has been triggered by the code. Further testing for the mobile application and its push notifications and Cloud storage will be done when the design is more developed.)

The transfer data of the recorded footage and images to the user's mobile application must be recorded. These recorded footages and images must be send to the right account and only be received by the user. Since a server is not established yet for the device to communicate with the mobile application, then the recorded footage and images can be sent to an email or similar type of storage to have the testers receive and observe the output result of the code sending footage and images.

If the device triggered during a scenario where car theft and car damage occurred and notifies and sends clear, visible recorded footage to the user's mobile application and Cloud storage, then the test is considered successful. Else, if the device isn't triggered during these scenarios or triggers during cases of false positives, then the data readings and the code that triggers the device through the accelerometer, gyrometer, and magnetometer should be looked into and done further testing to improve the device's functionality. Else, if the recorded footage and images taken aren't clear and visible enough to the user, then the camera must be checked for abnormalities and be fixed and be tested again. If the camera still doesn't provide clear recording footage and images then alternatives need to be considered to meet the requirements. In this case, the tye pfo cameras used might change in further testing or when the device is more developed.

At the end of the storage of recorded footage and images testing, these objectives should be reached:

- When the device is triggered by instances of car theft and car damage, recorded footage and images should be stored in the web application into Cloud.

- Push notification should be activated to notify the user of car theft and car damage even though their mobile device is silent.

- The recorded footage and images should capture the instance of car theft and car damage and be viewed properly and clearly by the user and anyone else.

- The time that the recorded footage and images are sent to the Cloud storage must be in real time.

7.4.4 Communication Connection Testing

The development team will implement the code that will connect the SSDC to the user's mobile application through WiFi or 4G. For this testing, the SSDC device will be observed on its connection to the user's mobile application through means of WiFi connection or cellular connection. The code implemented should output results that state if the connection is successful and when the connection is receiving buffering or errors.

The user's mobile application must first be connected to the SSDC device. This can be done by having the mobile application already using a local WiFi router or enable 4G and cellular data. The test cases will have the developers observe if the mobile application is connected to the SSDC and has a strong, efficient signal. This can be observed through the recorded footage live and received recorded footage and images in real time and the time it takes to get push notifications when the device is triggered. (Given that testing of the accelerometer, gyrometer, and magnetometer data readings tests and received recorded footage and images tests are successful) The results will be recorded to have the signal strength measured and it the time it takes to receive the recorded footage and images and if they are clear and efficient for the purpose of the SSDC device, which is to detect car theft and car damage.

Repeat the above testing, but at lower levels of WiFi or 4G to observe the results at weaker signals. The recorded results should be documented to state that the test cases here have lower levels of WiFi or 4G. These results should be made in comparison with the above testing. If the results are inefficient where recording live footage is slow, the time it takes to receive push notification, recorded footage, and images takes too long, etc., then the code should be looked into again to fix connection issues.

If the connection through WiFi or 4G is sufficient enough for the user to get recorded footage with no lag and receive push notification, recorded footage, and images in real time, then the testing is successful. If not, then the code should be reimplemented to improve the WiFi connections and to fix any errors or abnormalities. For every implementation it must be documented on the changes that were made and if the errors and faults have been fixed after retesting the WiFi connection. It should also be documented on the version of the code that was used for the test cases to observe its progression as the SSDC device is being developed.

By the end of the WiFi Connection testing, these objectives should be reached.

- The code should allow the mobile application and the device be connected through WiFi.
- The WiFi connection should be strong and efficient given that WiFi is available to the user.
- The WiFi should connect to detectable WiFi signals within range automatically.

(Note: Due to time and effort constraints, some of these objectives might not be reached during prototype testing and will be further tested when the SSDC device is being developed.)

7.4.5 GPS Tracker Testing

The development team will first implement the code that will use the GPS to track the user's device's position. The code should output if the connection of the GPS is successful or if an error occurs when it is running. The code should also output the location of the SSDC device when using the GPS using latitude and longitude as its measurements.

(Note: This testing should be tested along with the hardware of the GPS chip as the software is dependent on the GPS chip to receive the location of the SSDC device. This will also detect any errors and faults in either the hardware or software during testing. Test results and scenarios should document the conditions and measurements in both the hardware and software, such as the position of the GPS chip and the code's current output measurements of the location of the GPS chip.)

The device or the GPS chip will be enabled once it is powered by a voltage source and connect to the user's mobile application. These will be used to track the user's device. The testers will observe and record the listed device coordinates and verify the device is correctly outputting the devices accurate latitude and longitude.

(Note: This testing will be simplified for the prototype testing to have shorter distances to measure the GPS tracker's connection and accurate measurements. Further testing will have farther distances to test the accuracy of the coordinates and its connection between the SSDC device and the mobile application)

If the GPS was able to track the user's device's position in terms of latitude and longitude accurately, given some rough estimations, then the testing is successful and the GPS tracker functions properly with the device and mobile application. If not, check the coding on the GPS for any errors or abnormalities that create inaccurate values in the latitude and longitude. Each test case scenarios must be documented with the current version and new implementations of the code for the GPS tracker to keep track of the progression of the test results if they fix any errors and faults and if the the testing is becoming more successful to reach the requirement specifications.

By the end of the GPS tracker testing, these objectives should be reached:

- The code should allow the mobile application to detect the device's location through GPS.

- The GPS signal strength should be strong and efficient for the user to identify where the vehicle is located.

7.4.6 Security Testing

This testing will involve observing the security of the mobile application and its connection to the SSDC device. This is needed to ensure that the user's mobile device and SSDC device will be protected by harmful attacks from outer sources. An example of this is protecting the user's information and connection between the mobile application and the SSDC device by encrypting the data.

The testers will attempt to connect to the wireless network without previous knowledge of the password through the use of WPA2 cracking and bruteforcing.This is assuming the network is not breachable. The testers will then login as a valid user to the network. The code implemented must output that if a user is currently logged in to the mobile application to observe if the access to the mobile application is a success or failure.

The connection will be monitored between the device and the mobile application through the utilization of wireshark. Examinations and observations of the wireshark pcap file will be made to ensure that no unencrypted data has been sent over the network. If unencrypted data appears in the file, reexamine the SSL configuration. These test results must be documented on whether the data has been properly encrypted or unencrypted data has leaked in each test cases. The SSL configurations must also be documented for each test case to observe the progress of improving the security,

Assuming network connection is secure and SSL is appropriately working, the testers will then determine the pairing between the mobile application and the device. This requires downloading the application. Upon downloading the application, the testers will observe the availability to connect to the device and observe a password prompt upon pair attempt. If no prompt is provided then recheck the authentication portion of the program. The test results should record the inputted login information and the output response by the mobile application. It should be observed in the code if the login information stored was a success and if the authentication process has properly processed the login information and outputs the right response whether to let the user be allowed to access the mobile application with the right login information or prevent access if the login information is invalid.

The device should correctly implement numerous forms of encryption and authentication to ensure the device and the data are maintained securely. Best practices should be implemented and working correctly at a minimum of basic levels of security. Advanced security features such as two factor authentication are not necessary due to the level of data criticality. Each implementation should be recorded and what changes were made and who made them and an explanation on why and how it will improve the security and fix any errors or faults. Each test case should record the changes and implementations made before so to observe the progress of the security testing.

By the of the security testing, these objectives should be reached:

- The wireless access point should not be accessible or readable by users without the secure password

- The communication between the device and mobile application should be communicated over SSL

- The mobile application should implement best security practices for authentication

(Note: This testing will be simplified for the prototype testing and not all objectives will be reached due to time and effort constraints. The SSDC device and mobile application must be well developed before having proper testing of its security. For the prototype testing, the testers will observe and record if the current security implemented is functional and meets some of the requirement specifications. This will be implemented more in further testing.)

8.0 Administration

This chapter illustrates a few of the requirements placed out by the original ten page document request related to the senior design project as well as a few administrative details deemed prudent to the final project as determined by the senior design group. These include planning related information such as project milestones as well as the information related to finances and budgeting for the product as well as long term marketing information for the final product.

8.1 Project Budgeting and Financing

The project budget is $1,500 for development of the 3 PCB boards with components, 3D printed cases, 3 power cords, product box for one complete looking market ready product and assisting components. The sponsor is the company Deucei. The project funds will be supplied by the owner of Deucei. Each unit will cost $100 to make and sell for $300 retail at low quantity (under 100 units). At higher quantities (over 1,000) the price per unit goes down to $65 for the WiFi only unit. Each unit will sell for $250 retail. The 4G enabled unit will cost $95 to make each unit and the unit will sell for the $350 retail. The year 1 projection is selling both WiFi and Cellular units combined to make a total of 2,500 units for a total revenue of $575,000. The cost of goods will be $175,000 with a gross margin of $400,000.

The mass production of the product will include a roll out of 5,000 - 10,000 devices being produced. This will drive production costs down to $30-$40 per unit. The unit price could continue to decrease as more units are ordered. Bulk orders are known to save lots of money down the line. The product could become more of an expensive device if customers ask for it. The device could also include 1080p and 120fps camera or a 4k 60fps camera. Neither one is out of the question.

A kickstarter campaign will be held in May 2018. This will help to insure that the team is able to raise enough money to make a large bulk order of electrical components, plastic injection molds, and the money for making it through FCC testing, RoHS, Wifi Alliance, and other various testing. The Kickstarter will need to reach $200,000 or above to get the first initial orders.

If the kickstarter does not quantify the needed capital investment the company will need to look for venture capital. The design and utility patents that the company holds will provide value for potential investors. The company will ask for between $200,000 - $500,000 from investors. This will help secure the needed funds to hit production. The design will be completed by the in-house engineering team to help mitigate costs but the manufacturing will take place at multiple locations overseas. This will cut down the manufacturing budget enormously. The savings from using overseas manufacturers will ensure that the company can spend more money on development of new products and design.

With the device the company will also be able to collect road conditions, traffic information, and notify other cars of incidents or slow downs ahead. The app will allow users to stay connected and work together to improve drivers safety. This information will be sold to companies that need such data. This data has to be kept secure and users of the product will be aware that their data is being sold. This will make another argument that the company can produce revenue even after the sale of the device. This is a continually revenuing product after it is sold.

The SSDC will produce income from its hardware cost, data collection, and the ability to collect a cloud/data usage fee. There will be two versions of the camera. One version will be able to connect and send video over wifi only. The second camera will be able to send video over WiFi and Cellular 4G transmission on an LTE network. The user will have to pay Deucei a data fee to provide cloud service and data service to them. Thus insuring that all theft and vandalism is caught on camera. With users having the ability to check in on their car and receive instant video there will be a price associated with that service. This will help both the users and the company mutually. Cellular data plans will start at $19.95. This price will increase with the need of cloud space storage and the amount of storage and individual wants. The user will not be required to have cloud space storage but in order to have the full functionality of the camera it will be a good idea. This fact will also allow the company to generate financing and revenue long after the sale of the product. Below are some numbers based on a data price point of $19.95.

Data as a service table

USD	Year 1	Year 2	Year 3
Data Unit Sales	2,500	5,250	13,500
Data Revenue	49,875	104,738	269,325
Data COGS	35,000	73,920	189,000
Data Profits	14,875	30,818	80,235

Table 12: Costs and profits of data as a service ($)

There will be two final versions of the SSDC. A WiFi version only and a WiFi and cell phone chip version. One device will be able to send live video while on cell connection to the users cell phone. This table represents costs and profits for cell phone service. The costs associated with the cell service should run about $19.95 a month or $199 a year. As the years increase the team plans to me more of the devices for the demanding customers.

Wi-Fi Units only	Year 1		Year 2		Year 3	
Unit Sales	2,500	At $65	5,250	At $60	13,500	At $40
Revenue	$620,000		$1,312,500		$3,375,000	
COGS	$162,500		$315,000		$607,500	
Profits	$457,500		$997,500		$2,767,500	

Table 3: Unit sales for WiFi units retail $250, costs of goods sold, revenue, and profits

Cellular and Wi-Fi Units	Year 1		Year 2		Year 3	
Unit Sales	2,500	At $95	5,250	At $85	13,500	At $65
Revenue	$875,000		$1,837,500		$4,725,000	
COGS	$237,500		$446,250		$877,500	
Profits	$637,500		$1,391,250		$3,847,500	

Table 4:Unit sales for Cell and WiFi units retail $350, costs of goods sold, revenue, and profits

8.2 Project Milestones

Task	Start	End	Status	Responsibility
Ideas Paper	21-Aug	26-Aug	complete	Group 25
Group member task assignment	4-Sep	6-Sep	complete	Group 25
150 page project report				
Divide and conquer document	22-Aug	9-Sep	complete	Group 25
Table of Contents	4-Sep	10-Sep	in progress	Group 25
Updated Divide and Conquer	11-Sep	22-Sep	Complete	Group 25
75 Page Draft	23-Oct	1-Nov	in progress	Group 25
125 page draft	6-Nov	12-Nov	in progress	Group 25
Final Documentation	20-Nov	26-Nov	In progress	Group 25
Research, Cost Analysis, Design, Documentation				
Analysis/choosing of parts	4-Sep	18-Oct	in progress	TBA
Controller Software	1-Oct	TBA	researching	TBA
Financial Part Analysis	18-Oct	25-Oct	researching	TBA
PCB Design	15-Sep	15-Jan	researching	TBA
Power Supply Design	15-Sep	10-Nov	researching	TBA
Camera Choice	15-Sep	1-Nov	researching	TBA
Product Layout	18-Oct	25-Nov	researching	TBA
Development Plan	10-Dec	22-Mar	researching	TBA
Senior Design II				
Order and test parts	TBA	TBA	TBA	Group 25
Construct prototype	TBA	TBA	TBA	Group 25
Debugging and Adjusting	TBA	TBA	TBA	Group 25
Final testing	TBA	TBA	TBA	Group 25
Peer Presentation	TBA	TBA	TBA	Group 25
Final Report	TBA	TBA	TBA	Group 25
Final Project Presentation	TBA	TBA	TBA	Group 25

Table 13: Project Milestones

8.3 Team Roles

Matthew White at a high level is responsible for hardware design, exterior design and implementation of the hardware. This entails the design of both the schematic as well as the eventual creation of the model for the physical device. As acting company sponsor he also is in charge of determining financial purchasings and final decision on product selection. Alongside these tasks, he is also charged with managing all administrative content such as determining group meeting times and delivering and binding of the final paper submission.

The software aspect of this project relies heavily on the contribution of two key members: Austin Sturm and Timothy Deligero. These two members are solely responsible for the software design for both the physical SSDC device, the development of the middle server, communication protocol as well as the mobile application. Austin acts as design and engineering lead for the software aspect of the project, as well as lead developer for the physical device as well as the communication protocol and middle api server. Timothy provides support for those projects while taking on the challenge and acting as lead developer for the mobile application. Together the two contribute a large portion of the project after the hardware design and play a vital role in determining project requirements and constraints. Scott Levine assists as well in the development phases for all aspects of the software engineering, providing assistance where needed while maintaining his other duties.

Scott Levine is in charge of LED, button, and assisting with programming and software protocols. He is responsible for a portion of the PCB design for LED and button or buttons that will be implemented onto the board. Among these roles, hardware will be a primary focus. However, he will be assisting with programming the development boards further and he will help with programming and flashing the chips that are placed on the final PCB board. Amongst these responsibilities Scott will be able to assist other team members with any issues they have and act in a supporting role.

The physical layout and design of the SSDC is done in three sections of development. These sections are component selection schematic creation, and PCB design/manufacturing. Joseph LaBauve and Matthew White and Scott Levine are responsible for the hardware development of the SSDC. Joseph LaBauve is responsible for the cameras of the SSDC and assisting with the creation of the PCB design in Eagle and multisim. This includes the design choices for the camera components, PCB design choices such as materials, and development of PCB placement.

8.4 Parts Selection and Parts Cost

The parts were very carefully selected and may continue to change as time goes on. The TMS570LS3137 16-Bit and 32-Bit RISC Flash Microcontroller (MCU) was ordered from Texas Instruments. This MCU can handle the processes that it will need to run such as the processor to run the cameras, Wifi module, the GPS chip, the cellular chip, the accelerometer, magnetometer, and gyrometer data. The 8 band CC3120MODRNMMOBR Wifi chip was also ordered from Texas Instruments as well as the LM2592HVT-ADJ/NOPB 12v to 5.5v switching regulator. Many components from suppliers are proprietary. This makes obtaining them a slightly longer process. The FGPMMOPA6H GPS chip will be used in order to gain vehicle position and location. This will help insure that the user can find the car if it lost or stolen. This particular GPS chip was selected because it came with a nice development board to work with and it has 66 acquisition channels. The accuracy is less than 50 meters but during development that will do.

The cameras for development purposes are raspberry pi cameras. The imaging sensors have 170 degree lenses on them. These lens provide close to a 360 degree field of view for the user. This insures that theft is caught on camera. With two 170 degree cameras the user will be able to turn off the camera recording them. This is to insure privacy and rights to the driver of the vehicle. With full 360 degree video the driver would always be recorded. This will not be acceptable to all users. Although it will be beneficial to insurance companies not all drivers will like to have 360 degree while driving video. Although 360 degrees is great while the car is parked, it is not such a great feature while the car is driving. The cameras on the finished product will be a volume manufactured part. The team is currently in contact with suppliers like FRAMOS Technologies that supply imaging sensors. The imaging sensor that is of interest is the Sony IMX 327. The camera records in 1080p with a framerate of 60fps. The product will require two of these cameras.This image sensor is highly capable of low light conditions. So that makes it perfect for our surveillance applications.

The team is also looking into the video processor from Ambarella. Ambarella sells processors that can process the video with ease. If the team does not program a FPGA then an off the shelf video processor may need to be used such as Ambarella. Ambarella provides high quality with single or multi-channel recorders. The device is a multi-channel recorder. The processor can pass automotive testing. The processor is loaded with HDR, 3D noise filtering, smart auto-exposure, and full-resolution sampling. The higher resolution during wider video captured allows for a higher level of detail over all. The cost of this part is still unknown but it will be somewhere between $20-$40 in low quantity. There are cheaper video processors in the market such as Novatek. These processors are cheaper but also harder to obtain in the United States. There are many other video processors on the market as well. More research will be completed to really solidify the decision of the processor the company chooses. The processor chosen should be able to process two cameras at the same time making it multi-channel.

9.0 Conclusion

The documentation done for this senior design project was extensive due to the fact that this is a five person group, which under the conditions of the senior design course requires 30 pages per person, which for the team is a challenge as the resulting documentation will require at least 150 pages, not counting the title page, table of contents, and appendices, as most of the research and documentation is done in the body of the senior design paper. Also, while the team does have the majors required for the senior design project, the team still lacked in experience about documentation and building a design during the first couple days, which resulted in an arduous process of research for relevant data to be documented with the team's design for the SSDC device. Throughout the semester, the team members have learned a lot of the planning and requirements needed to make and implement a prototype design in the senior design project during the first semester.

The project idea of a security device for user vehicles for the senior design project was created and suggested by the head of the group Matthew White, which was to create a device to track and record instances of car theft and car damage as a means of security provided for the user's vehicle. This is an interesting and useful project idea that is very relevant to modern society and even the students on UCF campus as the security of users' vehicles is valuable and many students on the campus use the parking lot garages on UCF to be able to attend classes and have their vehicles parked as well. Afterwards a description of the project is made to create an end goal of the project as well as organize the roles of the team members in the group. The project is given goals, requirements specifications, house of quality, and hardware and software diagrams, in order to organize the what will need to be in the design of the SSDC device and what group members are comfortable in doing a portion of either the hardware or software of the senior design project. However, the roles and requirements are not final as further implementation and development in the design of the SSDC device. Also, it is possible that the group member roles can extend into each to help support the team members as a whole. This is also because some of the team members are inexperienced during the first couple days of the semester and further implementation design might take more experience. THe team members still learned a lot on the need for a description and goals as a means to organize the documentation and future implementation of the SSDC device.

Researching design standards and constraints was not too difficult as the dimensions, components, communication, data protection, etc. are already studied and given a lot of documentation on what would be needed for security devices as well as meeting the functions and plans of the SSDC device when being placed inside the user's vehicle in order to meet the project idea, which is to detect and record instances of car theft and car damage. There were many constraints to be found when using security devices inside vehicles such as law regulations, social issues, data protection and security, safety for the user, etc. The constraints and standards need to be considered when further implementing and building the design of the project as they are essential to the requirements specifications.

A lot of research was made for the SSDC device as the device requires multiple components, such as the accelerometer, gyrometer, magnetometer, GPS, tracker, cellular chips, Wi-Fi chips, etc. Some of these components are needed to detect the motions of the user's vehicle and any instances of car theft and car damage, some are used to connect the device to the user's application, etc. The team members tried to find any research relevant to the design of the SSDC device and anything related to security devices and car theft and car damage. The team members were able to learn a lot about the components of the SSDC device and how they work and technologies provided for those components as well the design for the mobile application and PCB for the SSDC device. One example is discovery of the MEMS technology for the accelerometer and gyrometer as they provide a lot of features that support the SSDC device and its purpose. Another example is learning on the accelerometer, gyrometer, and magnetometer will function and how it should operate in the detection of car theft and car damage to the user's vehicle. Learning the measurements in the X-, Y-, and Z- axis for these components is essential as detection of motion is needed in a 3D plane axes and the type of measurements as well as the direction in either positive or negative values is needed to distinguish each component from one another and be able to identify how it will be used in the SSDC device.

Planning and building the design was difficult as the team members were still inexperienced at the time of how the hardware, software, and security should be made. Fortunately, the research made before so makes up for that as the team was able to figure what would be needed in the design. The parts and components were needed to have an idea of the PCB design to have a representation of how the hardware will look inside the SSDC device. The software was represented by multiple flowcharts and diagrams to represent the objects, functions, and relationships and interactions between the objects. This will be used to have an idea what objects and functions needed to be ade and where the data must be processed and used to interact with each object as the software is designed for the device. The security is important as a means of protecting the data and user's information within the device. There were many methodologies found for the security and many things had to be considered such as the physical device itself and the user's mobile application connect to the device as well.

The prototype construction was an arduous process as being inexperienced with EAGLE for PCB design, it was difficult to build the schematic given the datasheets and pin layout of the chips to connect to the MCU. The group also had to find the appropriate chips and their datasheets to have proper connection in the EAGLE program for the PCB design. The team also managed to get most of the parts essential for the SSDC device and descriptions were made for each component used.

The prototype testing plan was made for the hardware and software sections of the SSDC device as well as having test cases relevant to the function and purpose of the device which is to detect and record instances of car theft and car damage occurring on a user's vehicle as well as sending notifications to the user's mobile application to notify the user of the vent occurring at the time. A lot of prototype testing would be needed for the accelerometer, gyrometer, and magnetometer as they are major components for the detecting the car's motion as well need to filter out any false positives to properly trigger the device. This also includes security testing, GPS tracker testing, sent and received recorded footage and images to the mobile application, etc. There are many testings needed for this device as it has a lot of components and there are test cases that can find any potential errors or improper functioning of the SSDC device.

The administration section is made to keep track of project's budgeting, milestones, and parts selected, and even the team's roles in the project. The project milestones state what needs to be accomplished in Senior Design I ad well as Senior Design II, but the dates for the second semester have not been decided yet, but will be fully realized when enter Senior Design II. The team roles are meant to give each member a part in the project according to what they're comfortable with, but can change in the future along with any project milestones as the design becomes more implemented and built.

Ultimately the group has learned a lot about what is needed for the SSDC device and planned out how to build the design, test it, and what the requirements specifications are. The group will still have to do further testing and probably change parts for the SSDC device to better suit the requirements as the device is still in a prototype stage. The team is better prepared for the second semester to develop the SSDC design more and be able to built it into a proper consumer product

Appendix A References

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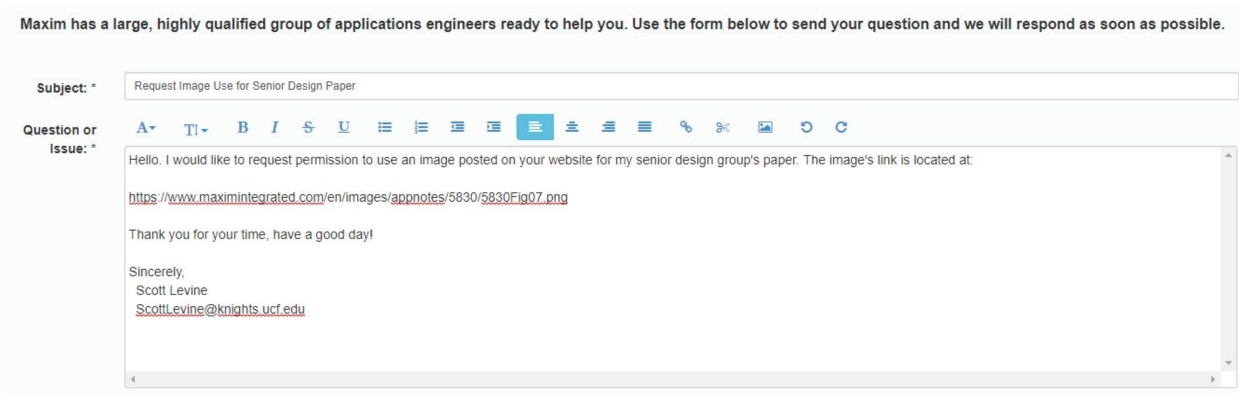
Appendix B Permissions



Maxim has a large, highly qualified group of applications engineers ready to help you. Use the form below to send your question and we will respond as soon as possible.

Subject: * Request Image Use for Senior Design Paper

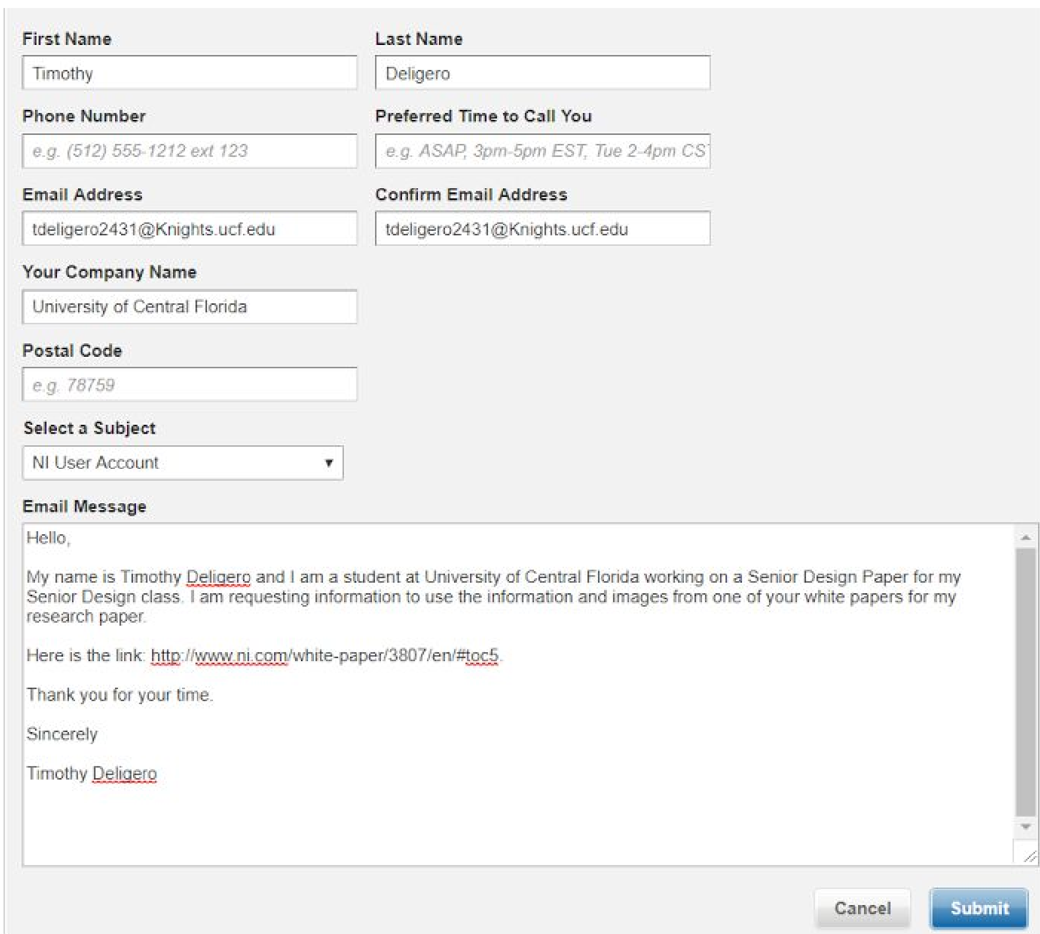
Question or Issue: *

Hello. I would like to request permission to use an image posted on your website for my senior design group's paper. The image's link is located at:

https://www.maximintegrated.com/en/images/appnotes/5830/5830Fig07.png

Thank you for your time, have a good day!

Sincerely,
Scott Levine
ScottLevine@knights.ucf.edu



First Name: Timothy

Last Name: Deligero

Phone Number: e.g. (512) 555-1212 ext 123

Preferred Time to Call You: e.g. ASAP, 3pm-5pm EST, Tue 2-4pm CS

Email Address: tdeligero2431@Knights.ucf.edu

Confirm Email Address: tdeligero2431@Knights.ucf.edu

Your Company Name: University of Central Florida

Postal Code: e.g. 78759

Select a Subject: NI User Account

Email Message:

Hello,

My name is Timothy Deligero and I am a student at University of Central Florida working on a Senior Design Paper for my Senior Design class. I am requesting information to use the information and images from one of your white papers for my research paper.

Here is the link: http://www.ni.com/white-paper/3807/en/#toc5.

Thank you for your time.

Sincerely

Timothy Deligero

Cancel Submit

Timothy Deligero
Today, 1:50 AM
info@circuitstoday.com

Reply all

Hello,

My name is Timothy Deligero and I am a student at the University of Central Florida working on a Senior Design Paper for my Senior Design class. I am requesting permission to use an article's information and images for my research paper.

Here is the link: http://www.circuitstoday.com/basics-of-microcontrollers

Thank you for your time.

Sincerely,

Timothy Deligero.

What's on your mind?

Hello,

My name is Timothy Deligero and I am a student at the University of Central Florida working on a Senior Design Paper for my Senior Design class. I am requesting to use the information and images from one of your tutorials.

Here is the link: https://learn.sparkfun.com/tutorials/accelerometer-basics

I am using the information and images from this tutorial to support my research paper.

Thanks you for your time.

Sincerely,

Timothy Deligero.

For which department?

General

Please include your email address if you'd like us to respond to a specific question.

tdeligero2431@Knights.ucf.edu

SUBMIT

SparkFun Customer Service <cservice@sparkfun.com>
Today, 12:07 PM
Timothy Deligero

Reply all

Type your response ABOVE THIS LINE to reply

tdeligero2431
Subject: Feedback from "What's on your mind?" at 2017-Nov-27 00:11 (anonymous)

NOV 27, 2017 | 10:06AM MST
Anna C replied:

Hello Timothy,

As we are an open source company, you are welcome to use that information in your project. However, we do ask that you make sure to cite us somewhere in the project.

Please let me know if there's anything else I can do for you.

Thanks and have a great day!

Anna Carlson
Customer Service
SparkFun Electronics
303.284.0979

NOV 27, 2017 | 12:12AM MST
Original message
tdeligero2431 wrote:

Hello,

My name is Timothy Deligero and I am a student at the University of Central Florida working on a Senior Design Paper for my Senior Design class. I am request permission to use the tutorial information and images for my research paper.

Here is the link: https://learn.sparkfun.com/tutorials/gyroscope

I am using the information and images of the gyroscope from this tutorial to support the research paper I am working with a group.

Thank you for your time.

Sincerely,

Timothy Deligero.

For which department?

General

Please include your email address if you'd like us to respond to a specific question.

tdeligero2431@Knights.ucf.edu

SUBMIT

SS SparkFun Customer Service <cservice@sparkfun.com>
Today, 12:07 PM
Timothy Deligero

Reply all

Type your response ABOVE THIS LINE to reply

tdeligero2431
Subject: Feedback from "What's on your mind?" at 2017-Nov-27 00:11 (anonymous)

NOV 27, 2017 | 10:06AM MST
Anna C replied:

Hello Timothy,

As we are an open source company, you are welcome to use that information in your project. However, we do ask that you make sure to cite us somewhere in the project.

Please let me know if there's anything else I can do for you.

Thanks and have a great day!

Anna Carlson
Customer Service
SparkFun Electronics
303.284.0979

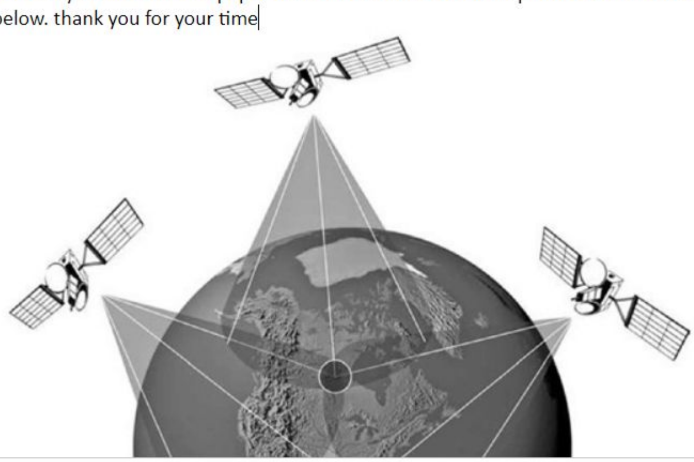
NOV 27, 2017 | 12:12AM MST
Original message
tdeligero2431 wrote:

To M mail@the-crankshaft.info × Bcc

Cc

copyright

Hi I'm a student writing a research paper for college, and I want to ask for permission to use an image of gps triangulation you have on your site. For the paper we have to ask via email for permission for each image we use. the image I wish to use is shown below. thank you for your time



Send Discard Draft saved at 8:22 PM

Submit the form

Submit the form below with as much detail as possible.

We will search

We will conduct a personalized search of our archives for all articles matching your criteria.

Get your results

You will be emailed a list of all articles found during your search.

Electronic design | Joseph

Jan 09 2014 | Deuce

5 | kooshyman@yahoo.com

Bill Laumeister | Phone

Hello I am contacting you with regards to a diagram of the layers of a PCB in your article. I desire to use this image with your approval in a paper as an illustrative reference. I know this issue can typically be resolved by the use of proper citation however in this case I am required to try to get approval for all images used in my student paper.

SUBMIT

Name *
joseph labauve

Email *
josephalabauve@knights.ucf.edu

Phone
Enter your Phone

Company
deuce

Service support type *
Other

How can we help? *

Hello PCBway,
I am contacting you today seeking to gain your approval to use an image you created in a blog post titled, "Printed Circuit Board (PCB) Design Issues." I desire to use this image as a an illustrative reference of current flow through ground planes for a student paper. Typically this is resolved by proper citation however for this assignment it is required to request use for any images used in the paper.

Which contact method do you prefer? *
(•) Email ( ) Phone

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Phone:+86 571 8531 7532
Fax: +86 571 8545 7578
Email:service@pcbway.com

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Your Name (required)

Joseph LaBauve

Your Email (required)

Kooshyman@yahoo.com

Subject

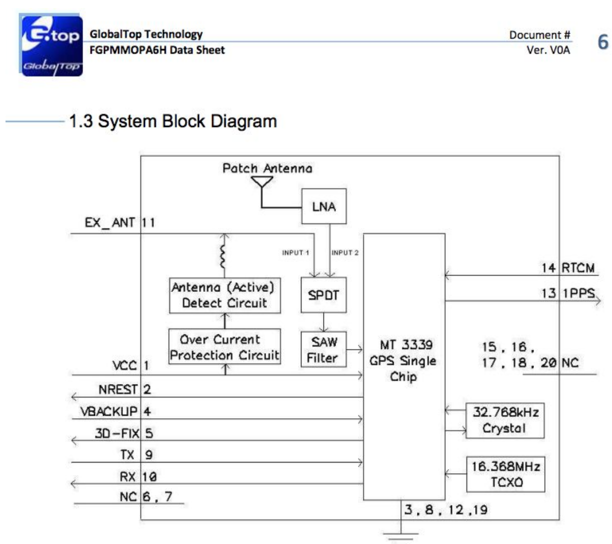
Copyright permission

Your Message

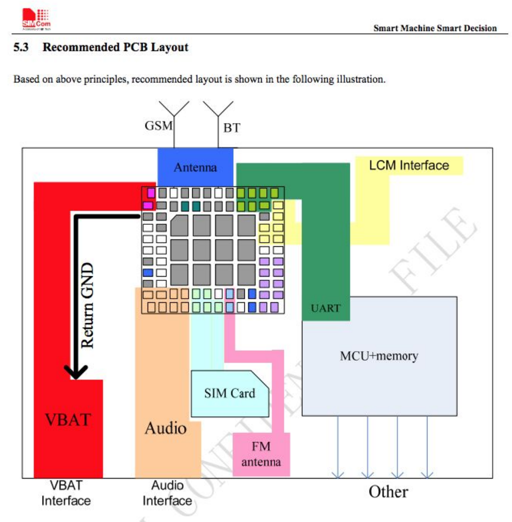
Hello I am a student writing a paper for college and wish to use your example of star grounding posted in an article written by Dylan Cottrell called grounding and shielding devices.

SEND

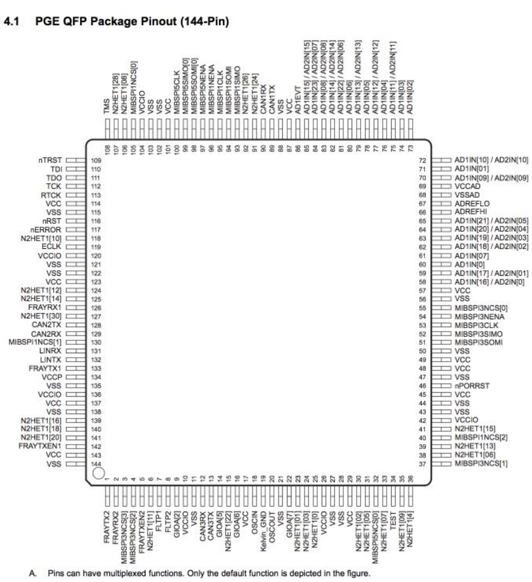
Appendix C Data Sheets



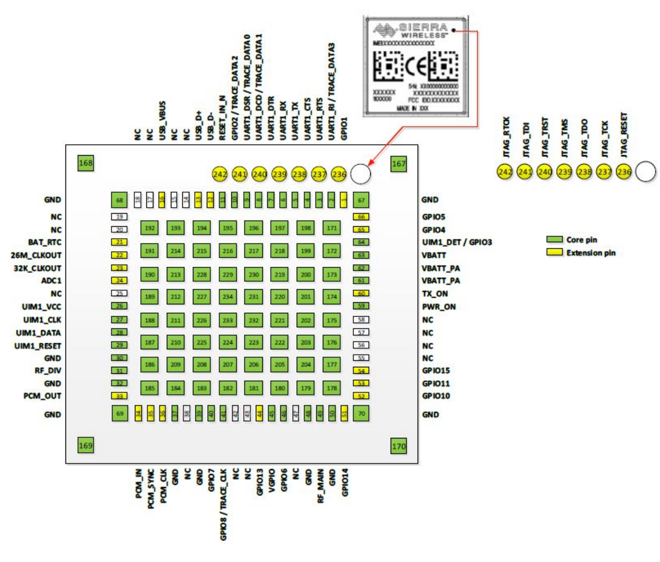
GPS FGPMMOPA6H system block diagram



PCB layout for 2G Simcom chip

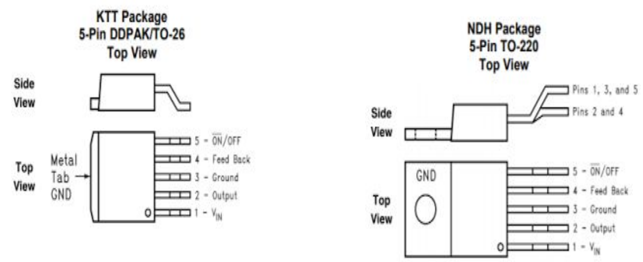


TI TMS570LS3137 MCU

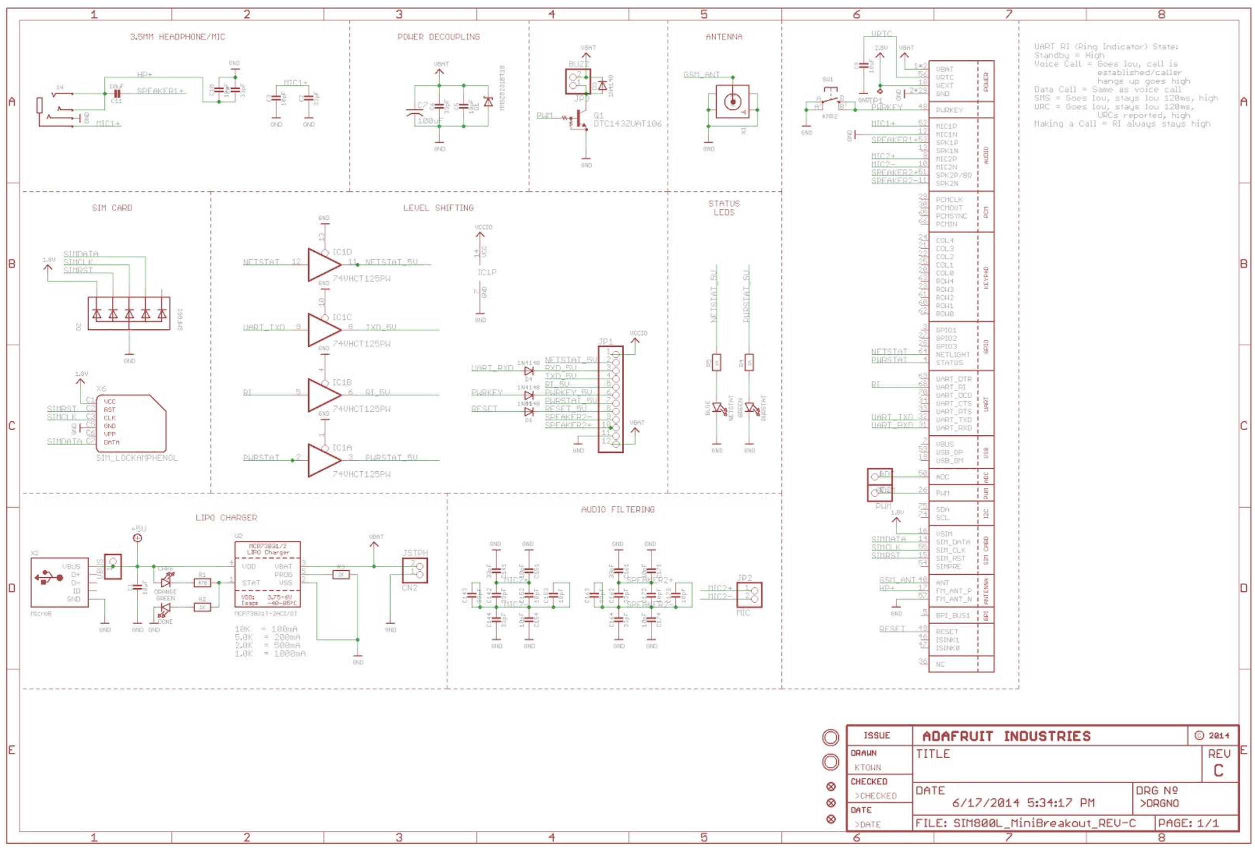


Sierra Wireless HL7588

6 Pin Configuration and Functions



http://www.ti.com/lit/ds/symlink/lm2592hv.pdf



Adafruit products schematic