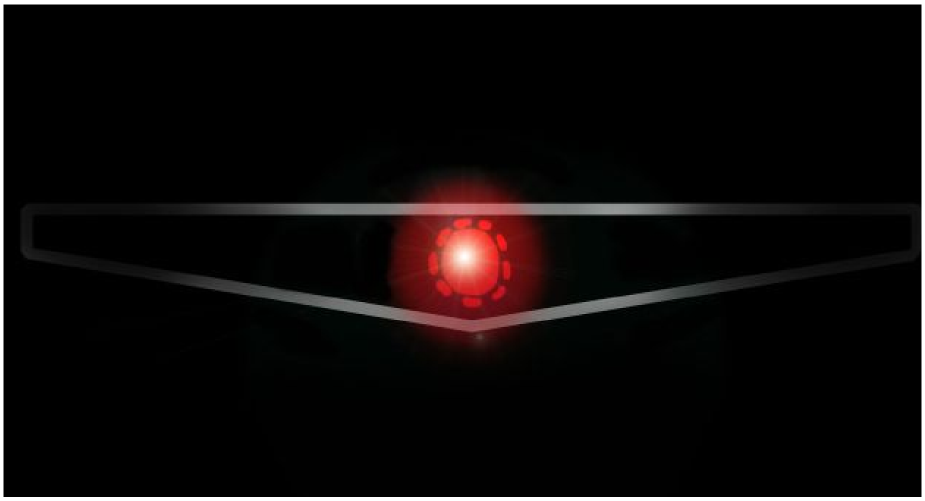
Senior Design I
CSS: Car Sentry System



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1. Executive Summary

The inspiration for this project arose from personal driving experiences and experiences with a dash cam. Driving is very dangerous and accidents can occur. Bad drivers can worsen these situations by leaving the scene. A dash cam oftentimes does not provide the quality necessary to make out license plate information and identify them. Higher quality ones that are able to deliver the resolution to do so often costs a fortune. Even then, the further away they are, the harder it is to make out the plate information. The solution to this is an automatic license plate reader (ALPR) that will scan and log the license plate information of all vehicles within its field of view.

The ALPR device for this project will have the objectives of being lightweight, low profile, and portable so that a user can place it in any car. It will also have the ability to run solely on battery power for several days. The device to be developed will be similar to a dash cam in the sense of the constraints imposed upon by the environment it is being placed in, that being, the windshield or the dashboard of the vehicle. This comes with size limitations and high heat considerations. These constraints will be driving factors in determining the outcome of the device, since it must be able to fit either behind the rearview mirror, somewhere on the windshield, or the dashboard. The last two options require that it is low profile so that it will not obstruct or distract the driver from the task at hand.

However, unlike a dash cam, which has to be constantly recording footage, the device will make use of computer vision to power the license plate recognition. This allows for frequent images to be taken and scanned to extract only the necessary information from the image before discarding the image. In this manner, the device will not have to consume as much power by constantly recording and storing the data. The objective is to save on battery life so that the device can last several days of a typical daily American commute.

Additionally, the device will also include a low power mode (LPM) that will conserve battery life even more by turning off all unnecessary components and only waking up to begin recording data when the on board accelerometer detects a jolt. This is expected to vastly extend the battery life. The default mode would be one in which the device is constantly scanning and logging data as it encounters them. A user will have the option to decide which mode fits their needs best.

Optimization of battery life is a major consideration due to the fact that the device will have a single board computing module that will be running the computer vision required to detect vehicles and scan license plates. This is an intensive task that requires a lot of power. It is also expected to generate a lot of heat in a small enclosure. This adds to the list of constraints and research into how to best optimize to reduce power draw and heat generation, so that the device may operate reliably as intended.

As with all modern electronic devices today, this ALPR will also include wireless connectivity so that a user can offload the data from the device onto their mobile device and sync it with the cloud. The decision to add a wireless component was made for the convenience of a user. It will give them options as to how to interact with the device. Most modern electronic devices have also now become internet of things (IoT) devices. It would be out of place and possibly a hindrance to users to not add in wireless capabilities. It will also provide additional backup security for the device. The mobile app will initially be a bare-bones app that will simply be able to sync the data and view data on the database. If time permits, this can later be expanded and fleshed out to provide more functionality for a user such as deleting data or updating device settings remotely.

The scope of the project can get very large very quickly when considering all the different license plates in existence and features for an ALPR. Therefore, the project will primarily focus on scanning Florida license plates and only storing the essential information, such as license plate information and vehicle model and color. The former will reduce the time necessary to train the algorithm and the later will save battery life and storage space in order to achieve the objectives of the project. Expanding the license plates that the device can reliably scan and adding in other features such as the ability to store images or record videos will become stretch goals that will be worked on if time permits.

2. Project Description

2.1. Motivation and Inspiration

Driving is a dangerous activity. People do not realize the risks associated with driving. When it is put into perspective, a human operating three-thousand pounds of moving steel barreling down the road with others seems daunting. To make matters worse, human error increases the chances of vehicle accidents to occur. Many civilian vehicles are not equipped with any form of surveillance camera systems to log these instances for insurance and/or legal purposes.

The motivation behind the project stems from personal experience driving around the city of Orlando and seeing first hand situations in which it would be useful to quickly obtain a vehicle's license plate information. This could be the case of a hit and run situation, reckless driving, simply remembering a vehicle for future reference, or any other myriad of reasons to obtain a vehicle's license plate information. Therefore, this brings up the biggest question, why not simply purchase a dash cam? As it currently stands, a good dash cam with reasonable video quality will cost more than a hundred dollars, if not even more than that. Even then, it might still be hard to read the license plate information of a vehicle more than twenty feet away since the dashcam incorporates a very wide field of view. Additionally, it takes up a lot of storage and fills up local storage rather quickly, thereby limiting the amount of data that can be stored and for how long. This could be remedied with cloud backups or manual backups, however this adds to cost and time. The alternative solution is a license plate scanner.

Automated license plate recognition (ALPR) has existed since the late 1970s. This form of technology has been and is currently being utilized by law enforcement. These computer-controlled camera systems are typically mounted on street poles, streetlights, highway overpasses, and police squad cars. In the field, ALPRs would automatically capture and store data, including but not limited to: license plate numbers, location, date, time, and photographs of the vehicle and the driver/passengers in the vehicle. This information would then be uploaded to a server. Data collected by these devices would be used by police for real-time and historical investigations and be used as evidence in a related crime.

In addition to law enforcement, technological advancements are being made in the automobile industry. Tesla, Inc. is notable for producing smart, autonomous vehicles. Autonomy is achieved by the implementation of cameras, advanced radar sensors, and advanced intelligence. While ALPR technology has not been incorporated in the production of Tesla vehicles, their features can be modified to increase functionality. A security researcher, Truman Kain, took it into his own hands to develop the Surveillance Detection Scout. In this project, Kain developed a computer that plugs into a Tesla's dashboard USB port (Greenberg, 2019). The computer then converts the vehicle's built-in cameras into a system that detects, reads, and stores license plate information and recognizes human faces. The security feature comes into play as the computer sends out an alert on the Tesla's display notifying the driver if it repeatedly sees a certain license plate or human. Kain's motivation for the project was to provide extra security for the user in the case that a perpetrator is preparing to steal or break into the vehicle.

In the case of the average day-to-day driver, they will not need excess power or capabilities required for law enforcement personnel or the luxuries of a Tesla. If we consider the price points of a high grade ALPR used in law enforcement and a Tesla alone, both are sold at exorbitant prices that are not feasible for a majority of people. Throughout this project, we will design an affordable license plate scanner that will meet the needs of an everyday driver and can be utilized in any vehicle. Existing ALPR technologies will be reduced in this project to lower the market cost while meeting minimum requirements to satisfy the needs of a daily commuter.

The driver will most likely need a device that will capture license plate information in the case they find themselves in a dangerous situation involving another vehicle. This will be achieved by developing necessary computer vision software while installing the required (and minimum) peripherals. Since the driver is not going to need to remember every vehicle encountered for an extended period of time, there will be no need for massive storage space (either local storage or in the form of cloud storage) or constant data flow found in law enforcement ALPRs. Due to the lack of advanced camera features and sensors installed in a majority of vehicles, there will also be a mobility factor, giving users the ability to configure the system based on their vehicle layout. This project will take the basic functionality of an ALPR used in law enforcement while taking the similar computer logic integrated into the Tesla with additional enhancements to increase performance and further decrease cost and power.

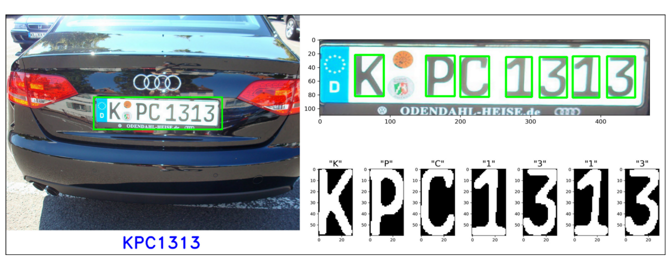

Figure 1: Example of License Plate Detection Using Computer Vision

A device capable of being able to instantly record a vehicle's license plate information provides the primary goal for creating a portable and low-profile license plate scanner for the average driver. The device will have the ability to log the date and time and obtain a vehicle's license plate information using computer vision (*Figure 1*) powered by openCV or Yolov5. Preliminary research seems to show the Yolov5 would be better at object recognition compared to openCV. However, upon further research, it was discovered that this isn't an either or question, instead, they can both be used in conjunction with one another to power the license plate recognition software. This would most likely be the better option since in this manner we would potentially be able to take advantage of the benefits of both while mitigating their shortcomings.

2.2. Computer Vision and Machine Learning

Through the use of computer vision, the capabilities of the scanner can also be extended to include logging a vehicle's color, and model, in addition to the license plate information. This will make it easier to distinguish data later when it is being reviewed. In this manner, the device will only be storing essential data about a vehicle rather than continuous video streams, thereby significantly reducing the amount of storage space taken up and greatly extending the amount of relevant data that can be stored on a local storage device. This will decrease the number of manual backups required in addition to freeing up the need for cloud storage services. Further saving on costs post-purchase.

Computer vision software will be running on a single board computer. There will be a camera peripheral connected to the board and it will have a quality of at least 1080p and greater than 20 fps to read vehicle attributes. The camera attached to the board will take images that will then be processed by the software. This will essentially convert the images of a license plate into pure text. Text extracted from a license plate image will then be stored in a local storage device located on the single board computer. Similar processes will apply when trying to record other vehicle attributes tied to a specific license plate. Furthermore, data will be collected from the peripherals connected to the project controller. Peripherals include the GPS and accelerometer. Not only will the software log information regarding vehicles within the field-of-view, but it will also document the current location and the speed of the vehicle the device is in.

Additionally, the camera will have the ability to read license plates up to 60 feet away and have a minimum field of view (FOV) of 90 degrees. Two options to achieve the 60 feet goal are digital zoom and physical zoom lens for the camera. The former would yield poorer image quality results, but would be cheaper in terms of components. Due to part scarcity, it may be impractical to purchase a zoom camera of sufficient quality. A compromise using both digital zoom and physical zoom may be required to achieve the objective of range while saving on costs. Furthermore, the FOV of the camera would have to be taken into account. A low FOV would require a pan and tilt mechanism so that the device is able to sufficiently scan all vehicles within view. This would not necessarily be required for a higher FOV camera, however it would need to have a high enough resolution to clearly obtain the license plate information. Otherwise, a zoom feature would need to be added, which would once again add to the cost. A technical and price comparison of different cameras would reveal which would bring the best balance in order to achieve the objective.

2.3. Mobile Component

For user convenience, data stored in local storage will also be accessible via mobile device. A Bluetooth module linked to the project controller will provide users the ability to connect their mobile device to the license plate scanner. When the license plate scanner detects that the vehicle is not in motion, the single board processor will begin to relay the stored data to the project controller. The range of the Bluetooth module does not need to be very far, since the device will automatically power down after it has remained idle for a while. So it is assumed that the use would be in the vehicle with the device. The data would then get sent to a mobile application on the user's mobile device via Bluetooth. Data obtained by the mobile device then gets stored locally until it can be transmitted to the database. The mobile application will be developed to allow for information to be extracted from the database and displayed on the graphical user interface of the application. It will also have the responsibility of syncing with the cloud database.

2.4. Battery Life

The goal is to have the CSS last a minimum of 3 days of a typical American daily commute as determined by the Census Bureau. Which is approximately 40 minutes to an hour a day (Census Bureau, 2021). The on-board accelerometer will come in hand in extending battery life as it can be used to determine the speed of the user's vehicle. The speed can then be used to set the frames per second (FPS) of the camera. The lower the speed, the less FPS necessary to obtain a suitable image to analyze. This can then be optimized so that the CSS is able to save on power consumption at lower speeds as it does not have to process as many frames as when it is at higher speeds.

Additionally, since a license plate scanner will not have to be recording a continuous video to obtain its data, it has the added benefits of an extended battery life over that of a dash cam. In fact, the goal is to have it run primarily on battery power rather than requiring users to supply it with power from the car like most modern day dash cams, however that will be an option for the user. Most dash cams currently have a small battery or use a super capacitor for the event of a sudden power loss so that the dash cam can have the opportunity to save data before shutting down. Since a continuous video doesn't need to be taken and constantly be saved, the CSS will be able to run solely on battery power if the user so chooses to do so. That way the user will not be required to constantly charge it.

The benefit of the increased battery life is that it provides users with flexibility in placement. Currently, most common dash cams require being wired in or plugged directly into a car charging port. In addition to the loss of a charging port, a user has to figure out a way to route the wires of the dash cam in such a way that the wires are out of the way and not distracting. Even then, bumps could knock wires out of place unless they are strapped down. As previously mentioned, the battery life of the license plate scanner would provide users with the flexibility of choosing whether they want to have it constantly plugged in or simply run it off the battery only and charging it only when necessary.

Because the device is portable in nature, multiple battery charging modes must be supported to provide maximum usability. The primary charging and operating power supply mode will see the device connected to a 12 Vdc power port in the vehicle. Since the vehicle power supplied fluctuates from 12.5 Vdc (Engine Off) to 14.75 Vdc (Engine on, Cruise RPM), the charging circuit of the CSS must be able to accept these fluctuating voltage values as well as protect from voltage sag and spike during the high current draw of starting the engine. Additionally, the CSS should be able to be charged from 120 Vrms mains voltage using a commonly available AC/DC converter. This gives the user intent on operating solely on battery power the option to either charge the CSS using an always-on 12V port in the vehicle while parked or to bring the device indoors with them and charge it from a wall socket. By facilitating both options, the primary goal of operating under battery power without cords is maintained while minimizing the possibility of the device running out of power.

Additional considerations for the charging circuitry is avoiding overcharging the battery, because overcharging damages the battery by (depending on the battery chemistry) reducing capacity, reducing lifespan, rapidly increased pressure, thermal runaway, or possibly combustion. Any power storage technology that is under consideration (Li-Ion, Li-Po, LiFePo4, Ni-MH, etc.) is sensitive to overcharging and careful consideration must be taken to ensure that overcharging is prevented. The charge controller must therefore be designed to incorporate some method of measuring the state of charge such that an accurate accounting of the battery capacity is recorded by the charge controller to measure the net charge being delivered to the battery. Offline methods are those which require the device operation be interrupted in order to measure indicators of the remaining charge capacity, but the system must be ready at any moment which renders any offline State of Charge (SoC) methods undesirable. This leaves only the online SoC measurement methods to be considered.

2.5. Modes of Operation

The battery life of the device can be further extended by programming additional modes of operation into it, so that a user can select the mode that best fits their needs. The default mode would have all components active and the device is scanning and logging the information of all vehicles with a license plate that comes into view. This would be detrimental to battery life, however, it would provide the user with the most amount of information.

The other mode would be a low-power mode (LPM) that would turn off all unnecessary components and only have the accelerometer and relevant components on. Then, when a jolt or collision-like movement is detected, the device will power up all components and begin recording data for several minutes before returning to LPM. In this manner it will increase battery life and reduce storage consumption even more. The circumstances in which to wake up the device can be determined later in testing.

2.6. Survivability

Since the device is intended to provide evidence in the case of a traffic incident, it shall be rugged enough so that the local storage medium is able to survive the incident and remain capable of supplying the recorded data. A suitable enclosure for the device would be able to provide for simple shock resistant internal mounting points for the device, while the enclosure itself would be secured to the windshield or dashboard of the vehicle with a suction cup or other non-invasive mounting device and able to withstand the forces present in a traffic incident.

Due to the prices of components currently and the cost of crash testing working components, a dummy prototype will also have to be built for the purposes of testing the survivability of the enclosure and PCB to see whether a local storage device would be able to survive in the event of a crash. Further research is required to determine the best way to simulate a crash on the enclosure, however a drop test is suspected to be sufficient enough to determine the survivability of the CSS by replicating the force sustained in an incident, the value of which would be chosen using traffic incident data from the National Highway Traffic Safety Administration (NHTSA) or other safety agency. Simple dynamics would permit the theoretical calculation of the parameters for the drop test, and the experimental forces could be measured by the accelerometer recording the data over probe cables long enough to traverse the drop height. More expensive components, such as the processor and single board computer, can be swapped out for dummy replacements in order to stay within the budget.

2.7. Constraints

As previously mentioned, the device will be portable. This is so that it can be placed on the windshield or dashboard in any vehicle with an enclosed space. With this feature, users are able to make adjustments based on their vehicle's dashboard layout.

This objective also results in a size constraint as the device must be able to fit on a user's dashboard or close to their rear view mirror. The system being developed will not cater to "open" vehicles, such as motorcycles, scooters, etc. Considering open vehicles will further decrease the size of the CSS, increasing the challenge in design. For safety reasons, when the device is installed in the vehicle, it should not be so large that it obstructs the driver's view or distracts them from driving.

Most of the constraints for the project arose from the environment in which the device would be subject to, a vehicle and for this project, one in the state of Florida. Therefore, the device must be portable and have a low profile so that it can be situated on the windshield of the vehicle or the dashboard. Additionally, a stationary vehicle in direct sunlight could reach temperatures up to ~150 degrees fahrenheit (Geggle, 2018). In addition to the extreme ambient conditions, the processing power required for computer vision would add excess heat that would compound the heat constraint. This means that the components of the vehicle must be able to withstand the high temperatures and continue to operate. This limits the types of batteries that can be used.

A super capacitor could be used to withstand the heat, however, it would not have the charge capacity required to power the device over the desired use case. Preliminary research reveals that lithium polymer batteries would be the best solution for a high temperature environment. Cooling solutions such as heatsinks, and fans will also have to be considered and most likely tested to see if they make a significant impact on heat reduction. Heatsinks would increase the size, and fans would also increase power draw. Therefore the solutions mentioned would be limited by the size constraint, as there is not much room to work with behind the rear view mirror. If placed in a different location, then a slim profile will still have to be considered as to not interrupt the driver's field of view. Testing would reveal which solution would be the best.

Regardless of the eventual choice of battery, the heat of the operating environment will necessitate rigorous monitoring of the thermal state of the battery especially during charging and high current discharge such as active image processing. This constraint might necessitate throttling based on the thermal condition of the battery, voltage regulators, or the single board computer, which will need to be implemented in such a way as to not interfere with the ability of the system to execute its functions in real time and therefore remain reliable. Once again the accelerometer can be used to determine prioritization. If a jolt is detected then the throttling may be temporarily overridden to prioritize scanning for a potential getaway vehicle.

For the purpose of demonstrating electronic design, we conclude that most of the peripheral sensors will be connected and controlled from a PCB of our own design containing a project controller. This controller will appropriately route data from the sensors to the single board computer for processing through the machine learning algorithm. Data will also be sent from the single board computer to the project controller to write to the SD card or transmit over Bluetooth for example. Taking the size constraint into consideration, we challenge ourselves to accomplish power and peripheral controls on one shield that can connect directly and sturdily to the I/O pins of the single board computer. This would realize the components listed in Figure 3 and Figure 4 on the same board.

2.8. Plug and Play Functionality

A great feature of dash cams is the plug and play functionality. Out of the box, all it needs is an SD card and once plugged in and set up, it is immediately recording. A user does not have to play with any settings unless they want to. CSS will also incorporate plug and play functionality to make it as simple and convenient as possible for the user to use the device. Once powered on and with an SD card slotted, it will automatically begin running in the default mode or whatever mode it was last set to. A user can change settings if they so desire but will not be required to do so in order to use the device.

2.9. Troubleshooting Features

Additionally, troubleshooting light indicators will be included on the device to assist the user in determining what the issue could be if an issue arises. Such as an indicator that lights up if storage is full or in the wrong format. Another indicator for battery status. These indicators will aid the user in quickly debugging the issue so that the device can go back to being used. They will also be helpful for testing the device.

The device is equipped with both high capacity on board storage as well as wireless communication in the form of Bluetooth, therefore more in depth but less essential troubleshooting or device health data can be provided to the user. Basic battery statistics useful for long term use such as number of charging cycles, maximum capacity degradation, temperature, critical temperature events, and remaining running time would be useful but infrequently accessed data for the user. Since the prominent online SoC measurement method will constantly measure the current entering and leaving the battery, the troubleshooting features are relatively simply implemented in the charge controller firmware as functions performed with the SoC measurement as input. The charge controller shall have non-volatile memory with enough capacity to store these values over the life of the device, and thus the integrity of the measurements can be retained in the event of off-controller storage change, such as formatting of the local storage. In the interest of power savings and extending battery life, the device health data will remain in on-controller non-volatile memory and a report shall only be generated and distributed on user request.

2.10. Market Comparison

Initial research of automatic license plate readers (ALPR) currently on the market reveals that they tend to be large, expensive, and exclusive to law enforcement agencies (Nelly's Security, 2021). These enterprise solutions are more than $500 per camera and some may even include software subscription fees. They also need to be hooked up to the car and mounted permanently. Additionally, a majority of these ALPR solutions are only available to law enforcement. The aim of the project will be to create a solution that is less expensive, portable, easy to set up, and potentially available to the public. The latter will need further research into, as Florida has laws and regulations (Criminal and Juvenile Justice Information Systems Council, 2016) in place with regards to ALPR. A lawyer may be needed as they would be best in determining the legal impact and responsibilities of making such a project available commercially or open to the public.

2.11. IEEE Student Grant Eligibility

One of our goals is to qualify for the IEEE Student Project Grant. To be eligible we must implement one or more IEEE standards with an IEEE Standard as the primary standard sought. The closest applicable standard found was IEEE 1725-2021: Standard For Rechargeable Batteries for Mobile Phones. This standard also specifies the use of rechargeable Lithium Ion batteries for a “host device” other than a mobile phone. In our case this host device would be the single board computer and/or the project controller.

In Figure 4 the interoperability of different parts of the power circuit are shown. One major limitation as previously stated is the environment. The battery system of our device needs to be capable of withstanding and operating in temperatures in excess of 150℉. Cooling methods may be further researched. The user of the device will receive indicator messages on battery state and/or warnings. An adapter, host device protections, and charge control will also be designed and must adhere to subsystem standards cited in IEEE 1725-2021. The battery pack may be designed using one or more cells that will be purchased. The subsystem standards must be followed in order to qualify under the 1725-2021 standard. The requirements are listed below in Table 1.

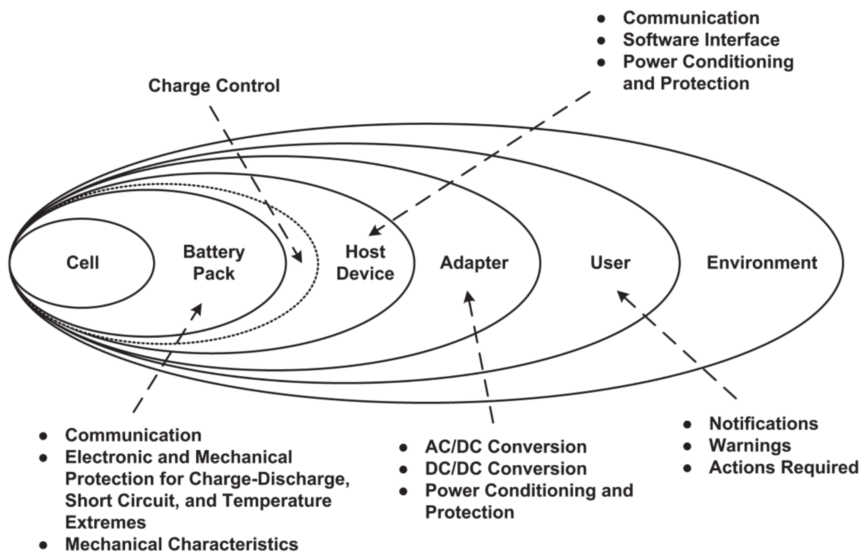

Figure 2: Achieving IEEE 1725-2021 Standards (IEEE, 2021)

System Component	Standard
AC/DC adaptor or charger	IEC/UL 60950-1 or IEC/UL 62368-1 and IEC 62368-3 or appropriate safety standard of destination country
DC/DC adaptor or charger	IEC/UL 60950-1 or IEC/UL 62368-1 and IEC 62368-3 or appropriate safety standard of destination country
Battery pack	UN Manual of Tests and Criteria, Section 38.3 Lithium Batteries and appropriate safety standard of destination country
Cell	UN Manual of Tests and Criteria and appropriate safety standard of destination country

Table 1: Minimum Subsystem Requirements for IEEE 1725-2021 Standard

2.12. Stretch Goals

The task of scanning license plates seems easy enough at a glance, however upon further analysis, it is actually a much more challenging task. Not only does each state within the United States have a different license plate, but each nation also has a different license plate. This would add time to training the computer vision software. To complicate things, vehicles can also have bumper stickers that could confuse the algorithm. Furthermore, there are different types of license plates for motorcycles and four or more wheeled vehicles. Therefore, the initial objective will be to train the program to recognize and read Florida license plates on a standard commercial four wheeled vehicle for individuals with no bumper stickers. This will greatly decrease the learning time for the algorithm. Fortunately, each state has standards that license plates must be held too. The usage of these stands would help in refining the algorithm. A stretch goal could be to expand this to vehicles with bumper stickers and plates from other states. The project could also be expanded to plates from other nations, if time permits. Additional stretch goals could include motorcycles, business plates, government plates, or more.

Extra features can be implemented to further enhance data security. In addition to the different power modes, we can consider the implementation of two different modes in regards to the type of data that can be saved as a stretch goal. The first mode is essential mode. This mode will enable CSS to store basic license plate and vehicle information, location, and timestamps needed in text format. The second mode would be an extension of essential mode. This mode will be a high security mode. With high security mode activated, CSS will not only store essential information from essential mode, but it will also capture and store video from the camera. For users who feel the need to have substantial evidence in the event of an accident, they can use text and video stored on the device. The only downside to the incorporation of high security mode is the demand for storage and excess power consumption for processing and storing footage. Additionally, these modes can also regulate the status of the fan. Depending on the mode selected and the temperature of the device, the decision can be made to have the fan on or off to either conserve battery life or be on to lower temperatures. This was made as a stretch goal, because the current two modes supported would only need to have the fan on (default mode) or off (LPM mode). However, with additional modes of operation, it may be useful to further optimize the usage of the fan to best fit the user's needs in a particular mode.

Another stretch goal would be the full implementation of a software platform to interact with and utilize the CSS. This software platform would go hand in hand with the mobile application to allow a user to access their data from a desktop computer or mobile device. The software will allow them to see a log of all the data they've collected so far, the number of occurrences they've seen a particular license plate, and even a map of the locations in which license plates were detected. Due to the scope of such a platform, this will not be high on the list of priorities as it could potentially result in missed milestones.

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3. Requirement Specifications

#	Project Standards
0.0	IEEE Standard 1725-2021
0.1	Battery Storage, Charging, Power Supply Sub-standards
0.2	U.S. License Plate Standards
0.3	European License Plate Standards *

Table 2: List of Project Standards

#	Objectives
1.0	Plug and play functionality
1.1	Lightweight
1.2	Feature a Portable Design
1.3	Crash Survivability
1.4	Prevent Obstruction in Driver View
1.5	Scan license plate information for enclosed, 4-wheel civilian vehicles
1.6	Identify vehicle attributes (Model and Color)
1.7	Build to IEEE/IEC/UL Standards

Table 3: List of Objectives

#	Hardware Requirements
2.0	Battery life will last several days (3 - 5 days LPM)
2.1	Camera of at least 1080p and greater than 20 fps to read vehicle attributes
2.2	Troubleshooting light indicators to indicate storage capacity and battery life
2.3	Overall design must be < 2lbs
2.4	Will not exceed a size of (5” x 4” x 4”)
2.5	Contain an accelerometer to monitor speed of vehicle
2.6	Bluetooth 5.0+ that is backwards compatible to sync to variety of devices
2.7	Will save data log information to local storage device
2.8	Have a GPS Module to determine vehicle location*
2.9	Enclosure is able to protect the local storage device so that it is still readable 90% of the time after surviving a two story drop

Table 4: List of Hardware Requirements

#	Software Requirements
3.0	Have the ability to recognize/read license plate information
3.1	Ability to detect an accident (impact vs. hard braking)*
3.2	Have the ability to offload data from local storage device
3.3	Have the ability to wirelessly backup data
3.4	Features multiple power modes to provide users with flexibility: ● Low Power Mode (LPM) - Only stores data when collision detected ● Default Mode - Always on and storing data
3.5	Automatically activate Low Power Mode (LPM) when the vehicle is stationary
3.6	Will have the ability to write vehicle attributes onto storage unit
3.7	The software/application will be synced to the hardware via wireless network*
3.8	Will have Active Mode which will turn on all components.
3.9	Have the ability to write location coordinates onto storage unit*
3.10	Features multiple security modes to provide users with flexibility:* ● Essentials Mode - Only stores license plate information, vehicle model, vehicle color, and time stamp. ● High Security Mode - Stores Video as well

Table 5: List of Software Requirements

#	Constraints
4.0	Weight
4.1	Environment (Car interior and temperature)
4.2	Time
4.3	Cost of System Controller
4.4	IEEE Student Grant Specifications
4.5	Image processing capability of controller/processor
4.6	Compatibility of Components

Table 6: List of Constraints

* Stretch Goal

4. House of Quality

The marketing and engineering requirements were measured using a house of quality diagram. This matrix depicts the impact of each marketing and engineering requirements against one another while identifying what can be achieved. Shown below is the house of quality diagram (*Figure 3*) for CSS.

		Engineering Requirements				
		Cost	Dimensions	Power Output	Setup Time	Weight
		+	-	+	-	+
Marketing Requirements						
Durable	+	↓				↓
Low Cost	+	↑↑		↓		↑
Easy to Use	+	↓	↓		↑↑	
Easy to Install	+	↓	↓↓		↑	↓
Small Form Factor	-	↓↓	↑↑	↓	↑	↑↑
Long Battery Life	-	↓↓	↓↓	↓↓		↓
		< $150	4"x4"x4"	< 30 Watts	< 5 Mins	< 5 lbs.

Legend			
Correlation		Polarity	
Strong Positive	↑↑	Positive	+
Slight Positive	↑	Negative	-
Slight Negative	↓		
Strong Negative	↓↓		

Figure 3: House of Quality Diagram

5. Block Diagrams

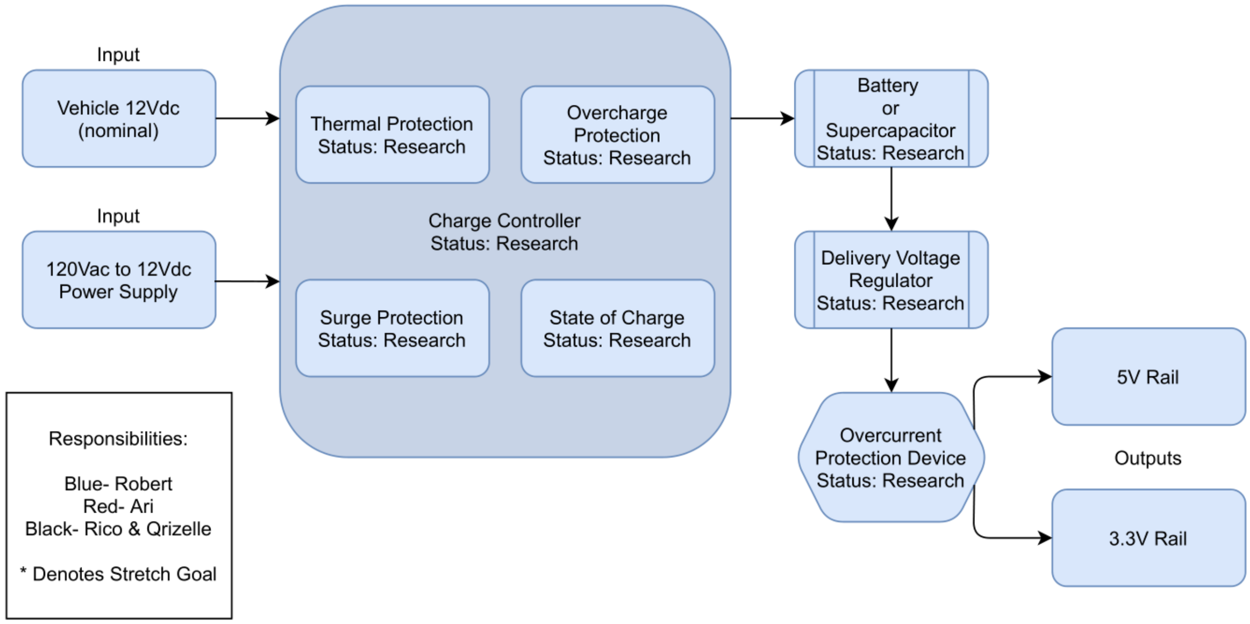

Figure 4: Power Block Diagram

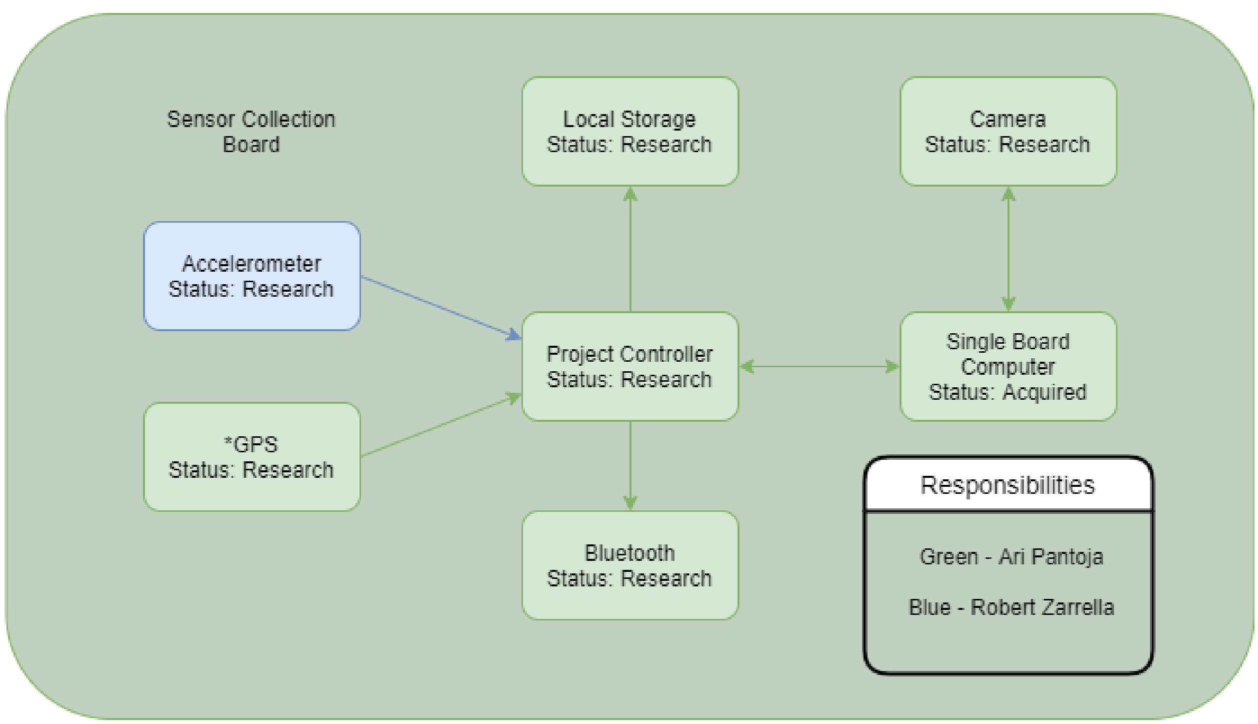

Figure 5: Electronics Block Diagram

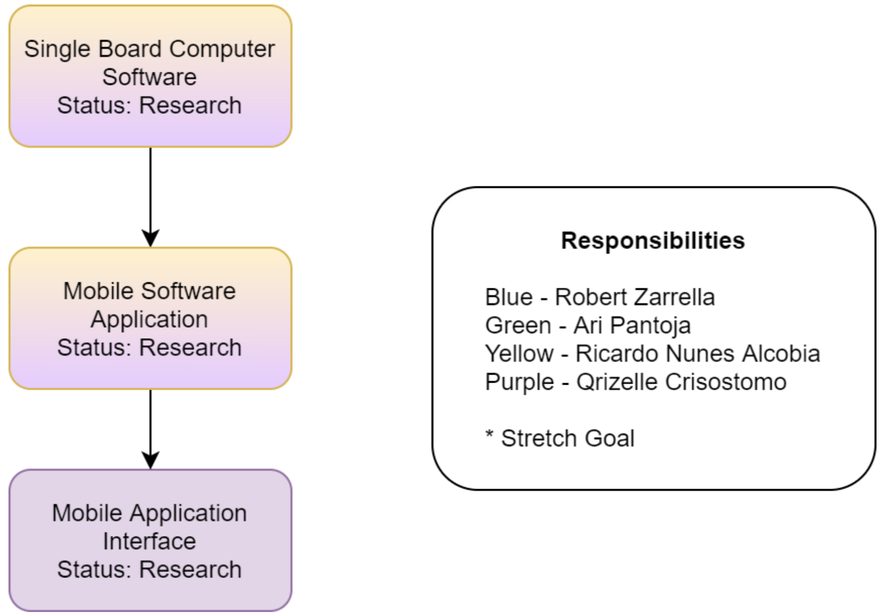

Figure 6: Software Block Diagram

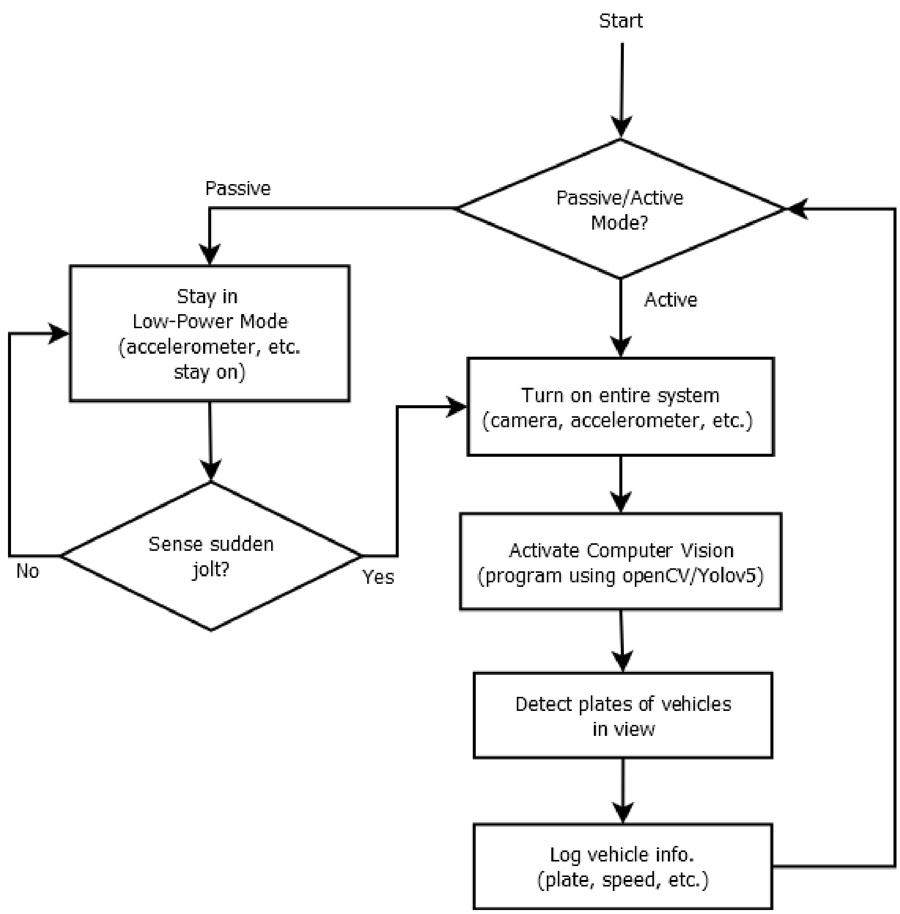

Figure 7: Single Board Computer Software Flow Diagram

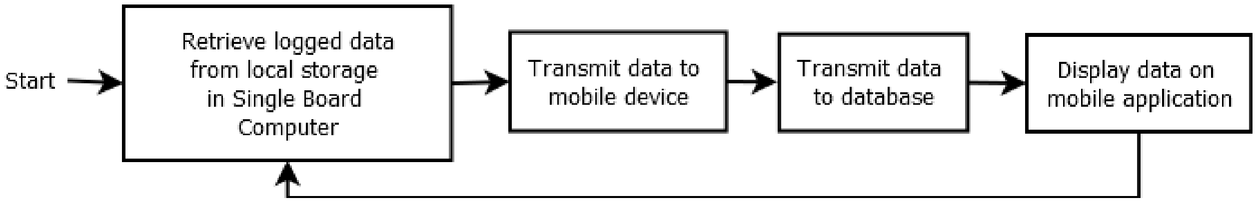

Figure 8: Mobile Software Application Flow Diagram

6. Estimated Budget & Financing

The budget will be self-funded with the anticipated assistance of the IEEE Student Grant. Based on current estimates, we may have an excess amount of funds considering the lower bound of the cost estimate. Excess funds will allow for further enhancements, cover the costs of broken/malfunctioning parts, or allow for duplicate purchases in case a part fails. Shown below are the estimated calculations for one-time purchasing.

Item	Quantity Estimate	Cost Estimate
Camera	1	~$5 - $30
Local Storage (circuit)	2	~$20
Bluetooth transceiver	2	~$40
Battery	1	~$80
Battery Regulator	2	~$30 - $40
Accelerometer	2	~$10 - $40
GPS Module	2	~$10 - $60
Printed Circuit Board	4	$50
Case	1	$22
Single Board Computer	2	$125
Project Controller	2	$30
Total Estimated Cost		$422 - $537

Funding	Assistance
IEEE Student Grant	- $500

Estimated Credit/Debit	+$78/-$37

Table 7: Project Purchasing and Financing

7. Project Milestones

Senior Design I	
Objective	**Time - Date of Completion**
September	
Initial D&C (<= 10 pages)	12:00 PM - 09/17/21
October	
Updated D&C (20-25 pages)	12:00 PM - 10/01/21
Order Parts/Resources	By 10/04/21
Acquire Parts/Resources	11:30 AM - 10/18/21
Develop/Test Version 1 of Software	10/18/21
November	
Individual Part Testing (Breadboard)	10/18/21 - 11/05/21
Senior Design I Report (60 Page Draft)	12:00 PM - 11/05/21
IEEE Application	11/08/21
Develop/Test Version 2 of Software	11/10/21
Prototype #1 Designed	11/12/21
Senior Design I Report (100 Page Draft)	12:00 PM - 11/19/21
December	
Prototype #1 Testing	11/19/21 - 12/03/21
Dummy Prototype Crash Testing	11/19/21 - 12/03/21
Final Senior Design I Report	12:00 PM - 12/07/21

Table 8: Project Timeline of Fall 2021

Senior Design II	
Objective	**Time - Date of Completion**
January	
Develop/Test Version 1.2 of Software	01/03/22
February	
PCB Design Testing Done	02/19/22
PCB Ready To Ship	02/21/22
March	
PCB Delivery	03/25/22
Begin Solder Process	03/28/22
April	
Have Working PCB	04/08/22
Final Testing/Revisions	04/01/22 - END
Peer Presentation	TBD
Final Report	TBD
Final Presentation	TBD

Table 9: Project Timeline of Spring 2022

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