Proximity-Based Hazard Detection System for Older Vehicles

Group Seven

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Motivation / Background:

With over 40,000 fatalities due to traffic accidents in just the year 2023 alone ([2] National Highway Traffic Safety Administration), the United States has a serious and often ignored or dismissed issue affecting countless families. The loss of a loved one from a tragic car crash may have been avoided if both parties had the most recent safety technology. But the potential life-saving technologies are kept out of reach of the average consumer because of the expensive cost. These technologies are a massive step up in safety for the average consumer and driver. They offer a serious change in the disturbing and tragically too common crash injury or fatality. If the majority of drivers on the road had access to these safety technologies, then maybe there would be a significant change to total crashes occurring and also the staggering number of traffic accident fatalities.

Not only is the loss of life frustrating to see, but the cost to our country as a whole is also staggering. According to the NHTSA data, serious and fatal traffic crashes cost the US a total of 1.85 Trillion dollars in value of societal harm. With 460 Billion dollars of that being economic costs and damages, and 1.4 Trillion in quality of life costs ([5] American Traffic Safety Services Association). Even a small percentage decrease in these numbers could mean huge benefits to the United States' economy as a whole. These safety features can not only save lives, but also save money for every consumer in general.

The expensive challenge that is gate-keeping the average driver is the cost of a new car. While new cars currently possess newer safety technologies, the average consumer cannot afford to drive to the dealer and drive off in a brand new car. According to Statista research, the average light car (gross weight of 8,500 pounds) cost approximately $47,000 in 2023 ([3] Statista). With interest rates included the total cost of a car loan for $47,000 could end up costing more than $60,000 over 60 months. This is not an easy expense for the vast majority of consumers. In 2023, the average American salary was approximately $59,423 ([4] Forbes). That means the average American would have to work at least one full year to afford a new car, which is not an option for the majority of consumers.

Once most consumers see the price tag attached to the shiny new car, they will be running in the other direction, sacrificing the amazing safety features that are available to them. The thought of average consumers not being able to protect themselves with more features available to them because of cost is a huge motivation of this project's undertaking. This project aims to enable consumers with an older model car that cannot afford the massive expense of a newer car the opportunity to upgrade the safety features in the current car they own. According to the Hedges & Company research survey, approximately 62% of all vehicles on the road in the United States are models from the year 2014 or older, and 23% of vehicles being over 20 years old ([1] Hedges & Company Research). We know in only the last 5-6 years that many of the incredible safety features have been included in car design with many of those years only offering the features through the most expensive trims and options.

So while these safety features are beginning to be implemented in newer model cars, there is still about two thirds of the consumer market that either cannot or will not purchase those newer vehicles. This makes the road today still unsafe compared to the possibility of the majority of consumers having access to these potential life-saving features. Our motivation and desire is to be able to arm the everyday consumer and driver with as many tools as possible to protect not only themselves, but other drivers on the road as well. If instead of only one third of drivers having the powerful safety features, everyone had access to these features, we predict a significant decrease to the number of total traffic accidents, which coincides with a decrease in total traffic accident fatalities as well.

The project design involves a modular system of printed circuit boards (PCBs) mounted on the vehicle's exterior and interior. A PCB mounted on the front bumper will collect and process visual data using a stereovision two-camera system to calculate distances to vehicles ahead and a camera system to be used to detect lanes. Up to four additional PCBs will be mounted on the quarter panels, each containing radar devices designed to detect objects in hazardous proximity, particularly to aid the driver when merging or changing lanes. This multi-sensor approach provides extensive coverage of the vehicle's surroundings, ensuring that the driver is aware of potential hazards on multiple sides.

The sixth PCB, located inside the vehicle, will interface with the sensor modules and provide feedback to the driver via a user interface (UI). This UI includes audio alerts through a speaker or buzzer, and visual data through a head-up display (HUD) projected onto the windshield. The HUD allows the driver to maintain focus on the road by displaying important alerts directly within their line of sight, eliminating the need to glance down at a screen or dashboard. The radar PCBs will be powered by a solar battery system, enabling continuous operation even in low-light conditions. The front bumper and interior PCBs, however, will be powered by the vehicle's 12-volt battery, utilizing proper power regulation and management to ensure efficient and reliable performance.

The goal is to develop a minimum viable product (MVP) that includes two radar modules, lane detection capabilities, and audio feedback. By offering a system that can be easily installed in older vehicles, this project seeks to make advanced safety features more accessible to the average driver, ultimately reducing the number of traffic accidents and fatalities on the road. If more drivers are equipped with these powerful tools, the result could be a significant decline in traffic accidents, injuries, and fatalities, making roads safer for everyone.

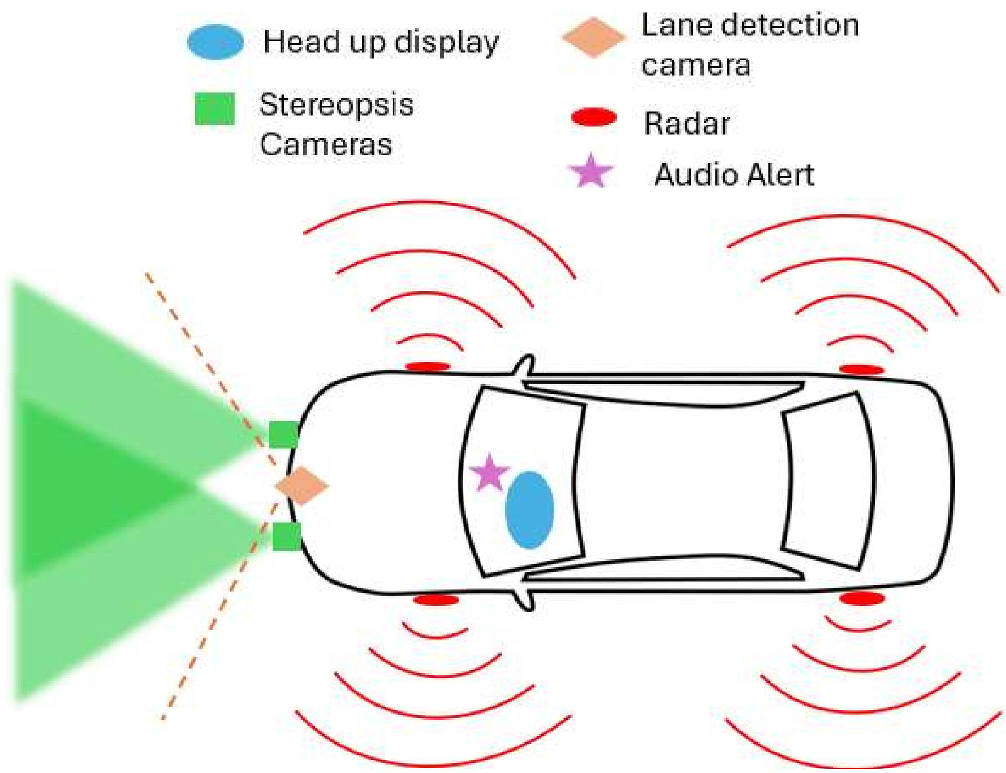


Figure 1. Sensor and UI layout

Goals:

Basic Goals & objectives

Basic Goals	**Objectives**
Alert driver of hazards with multiple sensory feedbacks.	Implement a buzzer or speaker to sound when a sensor has detected a hazard, or hazardous situation.
Provide blindspot detection for multiple vantage points of the vehicle.	Integrate 2 low power radar sensors into two external peripheries placed on the front quarter panel of the vehicle.
Real time communication of hazards between wireless peripheries and UI.	Implement a closed wifi network between the radar boards and the alar producing boards with a 2.4GHz wifi signal.
Provide lane keeping assistance.	Use a 1280 X 720 RGB output camera to collect roadway visual data. Process images with greyscale, Sobel filter and Hough transform to detect road lanes and send feedback to the driver if needed.

Advanced Goals & Objectives

Advanced Goals	**Objectives**
Provide a visual interface for operator accessibility that allows users to keep eyes on the road while receiving feedback from the device.	Design and implement Head Up Display **(HUD)** that projects on windshield in front of drivers point of view.
Provide 180 degrees of data for potential hazards.	Implement a low power radar on each quarter panel to detect hazardous objects.
Provide tailing distance (distance between operator's front bumper and the vehicle in front of them).	Use two cameras is a stereovision system to calculate depth and distance from camera to object using lens equations.
Provide dynamic tailing distance adjusted for rad speed.	Use a GPS to calculate road speed. Use calculated road speed with stereovision data with the convention of 2 feet per mph to give operator tailing distance feedback.
Reduce power consumption and performance of the front module by optimizing the device for lane detection.	Implement lane detection algorithms via logic on FPGA dedicated to lane detection. Paralleling algorithms to reduce computation time and optimizing unused components.

Stretch Goals & Objectives:

Stretch Goals	**Objectives**
Provide more contextual and varied visual output based on hazard type.	Implement multiple changeable stencils for the HUD system. Use a motor to change between stencils based on the hazard being communicated.
Provide a system that stays on for extended periods of time.	Use a combination of solar power and power management to ensure peripheries that are not attached to the vehicle battery maintain operation. Even in low light and throughout the night.
Design with weather rating	Design enclosures with IP69 weather casing for practical outdoor use.

Features / Functionality

This system is designed to enhance driver safety by detecting potential hazards on the road and alerting the driver through two distinct alerting methods: visual and audio feedback. It incorporates five primary detection areas using cameras, radar units, and GPS to provide a comprehensive view of the vehicle's surroundings and driving conditions, ensuring both proximity awareness and lane awareness.

The system operates by analyzing data from multiple sensors mounted on the vehicle. One camera located on the front bumper collects real-time visual data of the roadway ahead, which is processed by onboard software or logic to detect lane boundaries and adherence. A second system of cameras incorporates stereovision to determine the distance from this front bumper to the vehicle in front. This enables the system to assess whether the driver is maintaining a safe following distance. Additionally, GPS data is collected and used in conjunction with these proximity measurements to refine the determination of safe tailing distances using the 2 feet per mph convention, ensuring greater accuracy based on speed and road conditions.

For enhanced side view detection, radar units are installed on both the left and right sides of the vehicle. These radars are tasked with detecting obstacles, particularly vehicles in adjacent lanes that may enter the driver’s blind spots. The system is particularly useful for merging or changing lanes, where visibility is reduced and the risk of a collision increases.

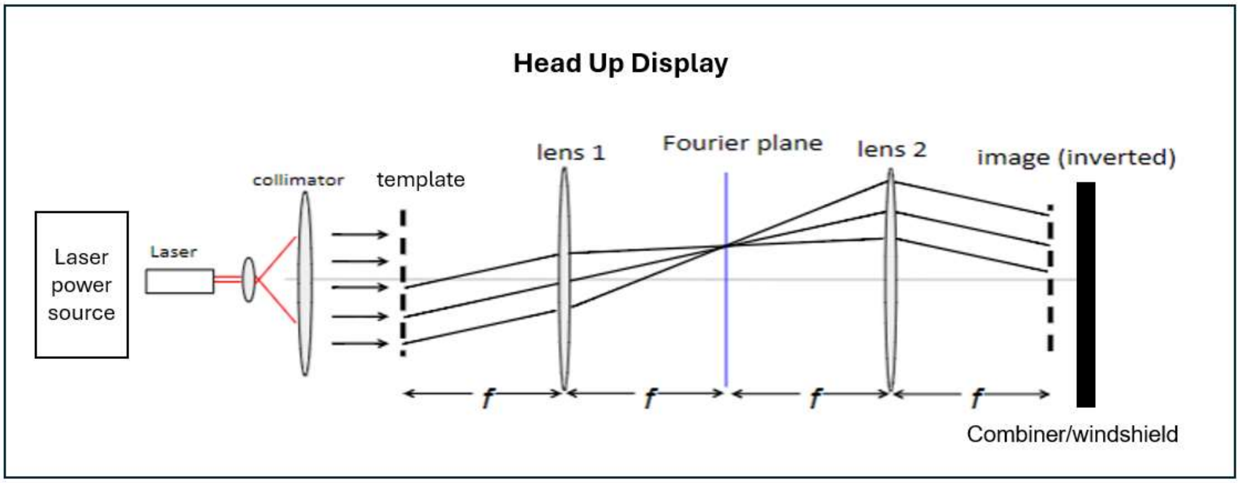
A head-up display (HUD) is the primary visual alerting method. The HUD projects critical information onto the windshield, directly in the driver’s line of sight. When a hazard is detected, the display provides clear and intuitive indicators about the nature and location of the hazard, allowing the driver to respond quickly without having to shift their focus from the road.

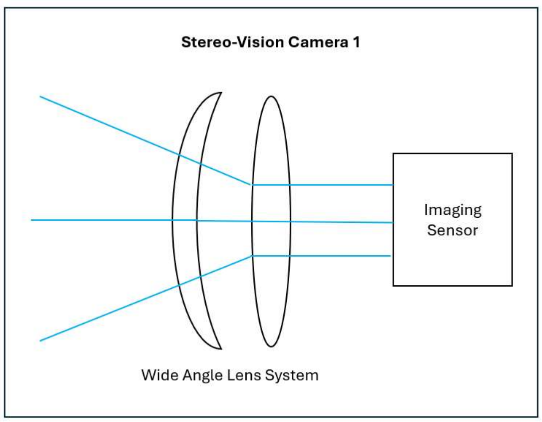
In addition to the HUD, a buzzer or speaker that provides audio feedback is used as a redundant alerting mechanism. The system emits beeps or ringing sounds when a hazard is detected, ensuring that drivers are notified even if their attention is diverted or visibility is reduced. This dual-mode alert system makes the system more accessible to drivers with either auditory or visual impairments, enhancing overall safety and usability.

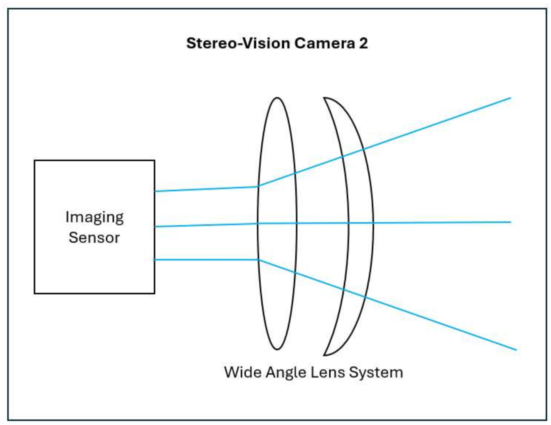
The system’s architecture is designed to balance real-time responsiveness with low power consumption. Data from external peripherals such as cameras and radar sensors are transmitted wirelessly to a central processing unit located within the vehicle. The wireless transmission uses Wi-Fi technology, chosen for its high bandwidth and low latency, which is essential for ensuring real-time hazard detection and alerting. However, the higher power consumption associated with Wi-Fi necessitates a design where peripherals operate independently as much as possible. To conserve power, these external sensors only transmit data as an encoded flag when a potential hazard is detected.

The MCU within the central unit is responsible for analyzing the incoming hazard flag data and configuring the output on the human machine-interface. The HUD and buzzer then alert the driver with the detected information.

Optical Schematic Diagrams:







The optical block diagrams depict the main optical components of the system, the head up display, and the wide angle lens systems for the stereo-vision cameras. The head up display consists of a red laser, coupled into a beam expander and a collimating lens, an inverted mask of the image to be displayed acting as the object of the system, two lenses of equal focal length aligned to create a 4f system, and the combiner on the windshield, acting as the image plane of the system. The design utilizes the principles of Fourier transform to project the desired image onto the windshield. The lens system to be added onto the cameras used for stereoscopic vision calculations will be designed to increase the field of view of the cameras, while minimizing distortions of the output. Introducing multiple lenses into the system will cause the distortions to accumulate, so the goal of the design will be to utilize as few lenses as possible while still obtaining the desired field of view.

Existing product / past project

Products with overlapping features and scope include the crutchfield Brandmotion FLTW-6000[1]. At $679.96 the FLTW-6000 utilizes two radar modules to detect hazards in the driver's blind spot and sends feedback to the driver via a buzzer and visual alert lights placed at the operator's discretion. The device is programmed to discern warnings vs alerts as only the light is illuminated if a vehicle is present while the alarm sounds if the driver starts moving in the direction of the detected hazard. All features are implemented via wires that must be run throughout the vehicle and pass though from interior to exterior in order for operation. The external units are IP69 water rated, something that is likely inaccessible at our price point. The field of view of this system is limited to the front quarter panels.

Figure 4. Crutchfield Brandmotion FLTW-6000

Bari Life provides the Car Blind Spot Monitoring System[2] **(CBSM)** at a price of $58.30. The Car Blind Spot Monitoring System employs 58 KHz ultrasonic sensors for obstacle detection. Feedback in this system is provided by two adhesive lights placed inside the vehicle preferable inside the door opposite the side mirror. A buzzer is also used to alert of immediate hazards. Both of these solutions run solely off the vehicles 12v power making power reliance simple. This in trade makes installation more complex as wires must be fed between the interior and exterior of the vehicle. The CBSM must also tie into the vehicle's brake lights for power. This wiring may make the device inaccessible for many especially those unfamiliar with vehicle wiring.

Figure 5. Bari Life Car Blind Spot Monitoring System

Past projects within UCF’s ECE senior design include group 5 of the 2020–2021 design period Enhanced Driver Awareness Detection System **(EDADS)**. Their system implemented cameras for visual spotter assistance, proximity sensors via 58 KHz ultrasonic sensors for rear hazard detection and resistive temperature sensors for engine health monitoring. The premise of their project was aimed at the sport of off-roading and navigating difficult terrain as opposed to general road safety. They wanted to implement a system that could stand in for a terrain spotter and provide enough data to the vehicle operator to navigate tough and complex terrain. Team 5 used two front facing cameras and one rear facing IR camera for visual data. The ultrasonic sensors were used in tandem with the cameras for a more accurate judge of depth and distance from hazardous rocks than the camera could provide, especially in the low light IR settings. Their system was completely implemented with extensive wiring and modifications to the vehicle within which it was installed. The EDADS team used an LCD as well as a HUD to interface with the operator. In their table of specifications the HUD was used to display if hazards were within a 2 foot proximity while more intricate visual data was left to the lcd screen mounted on the dashboard. This approach was more practical with their goal as off-roading does not require

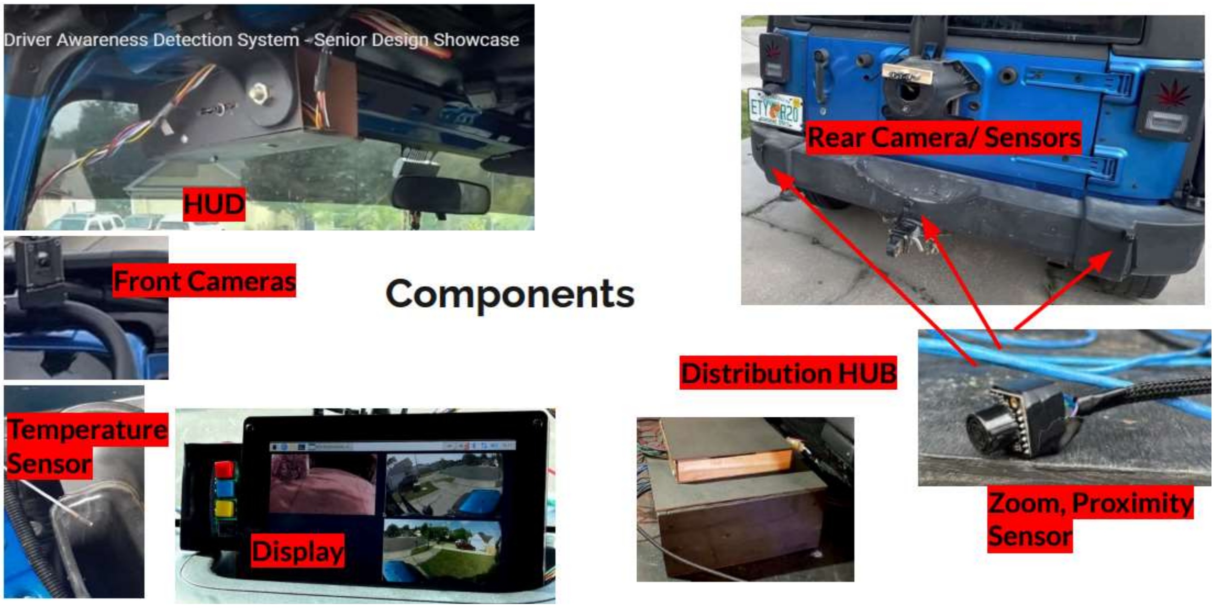


Figure 6. Enhanced Driver Awareness Detection System

ECE Senior design group 5 2020–2021

constant roadway line of sight, but rather close analysis of the terrain around you. You are generally moving much slower and are required and permitted to take time making your decisions. The EDADS team also included a thin film combiner on their windshield to enhance the visibility of their HUD system. Their HUD was two fold magnified and projected from an OLED screen. We hope by using a laser projection through a stencil we can produce a clearer, more vibrant image for the user.

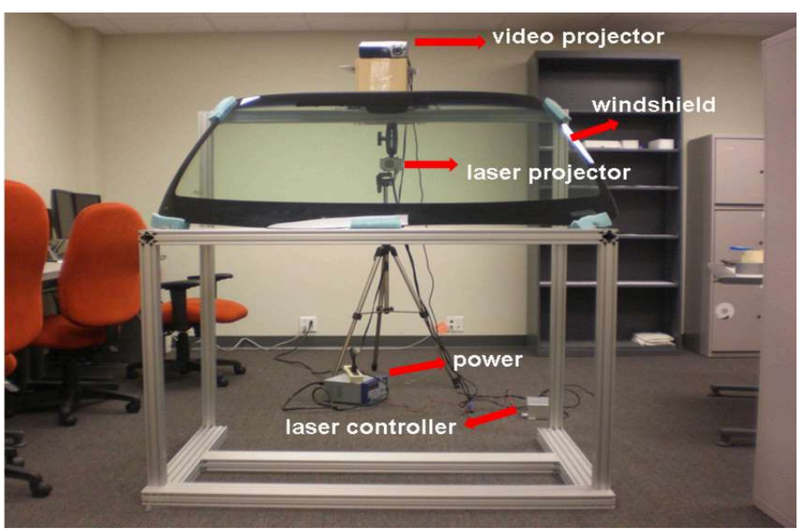


Figure 7. Prototype of Full windshield HUD
([8] Wu, Wen & Blaicher)

HUD systems are the most novel aspect of our design. While there do exist some aftermarket options most pedestrian vehicles that include HUD are only those luxury or EV models. Some manufacturers such as GM have experimented with incorporating systems as ambitious as full windshield HUD. These experiments seem to have taken place in 2010 but have lost traction. These HUD systems went as far as highlighting and projecting a circle around hazards detected by the camera when observed from the driver's seat. These hazards could be pedestrian signs, and other obstacles in foggy conditions. The windshield in this experiment incorporates a thin film with phosphorus coating which lights up distinctly under the photons shot by the laser projector.

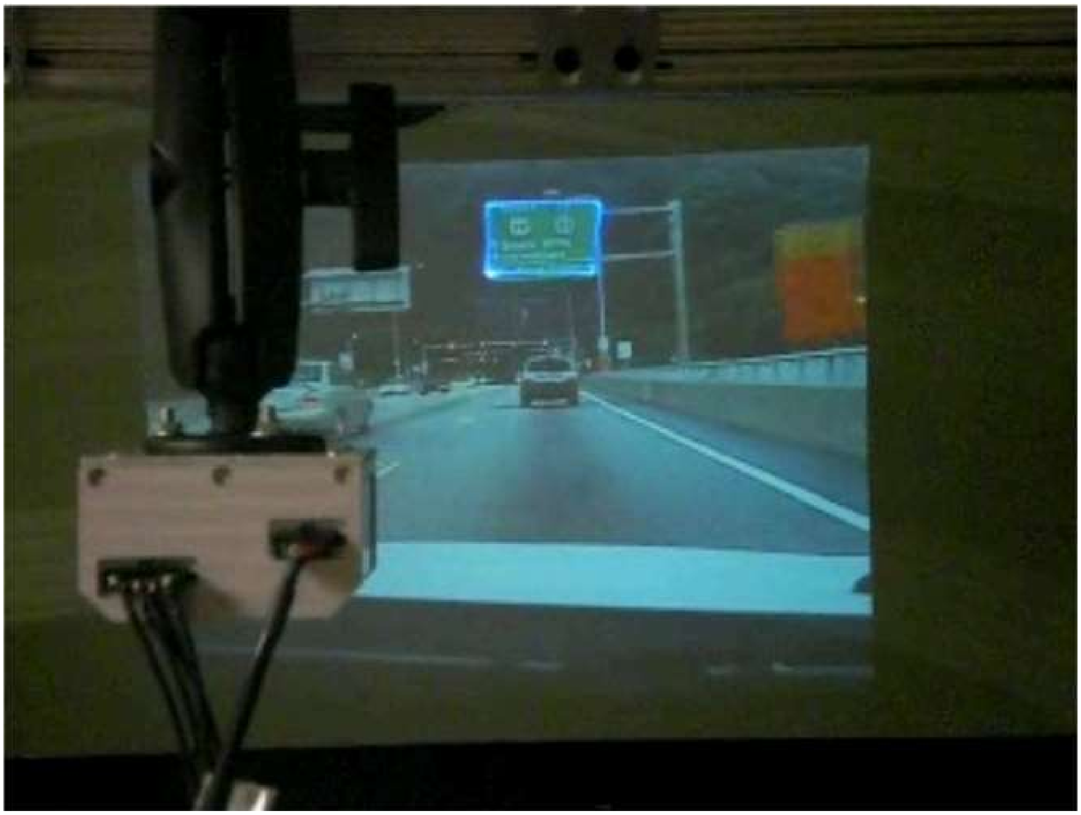


Figure 8. A road sign being highlighted by HUD
([8] Wu, Wen & Blaicher)

Many fully incorporated Advanced Driver Assistance System ADAS systems exist in the world today and features such as Automatic Emergency Braking **(AEB)** will be required by law in the United States by 2029. These systems directly interface with the operation of the vehicle with capabilities such as automatic braking and steering assistance. These systems can interface through the CAN (Controller Area Network) bus via codes which are usually proprietary to the vehicle designer / manufacturer. Modern vehicles also often use an electric line break which is easier to interface with software than the hydraulic brakes that dominated the market in the twenty tens and earlier, the market that this type of product would largely target. Because of the more mechanical implementation of car systems in older vehicles after markets ADAS are limited to alert features and observation assistance similar to our design.

Other aftermarket HUD products are mostly limited to a variation of a 7 segment LCD display. They are generally used for displaying speed but some do interface with the CAN to read things such as check engine lights and battery level. Some of these datums may not transfer over to the device depending on whether things like fuel level are mechanically measured rather than an electronic sensor. From our research, there are currently no aftermarket HUDs available that will alert the user for hazards detected in their blind spots.

Our product stands out by offering a seamless interface that delivers both visual and audible feedback to the driver, covering not only obstacle detection but also lane following and tailing distance monitoring. Unlike competing products that typically offer these features individually and often require professional installation, our system aims to consolidate all of these safety features into a single, easy-to-install package. This design's most ambitious stretch goal is that any typical driver can set up the device in their vehicle without specialized assistance. By providing real-time, actionable information, the system enables drivers to respond more quickly and effectively to the numerous hazards they encounter on the road, promoting a safer and more informed driving experience.

System Performance Specifications

System Requirement	Requirement Specification	Unit
The system shall alert the user of hazards detected within the specified range.	2	meters
The system shall produce an audible alert within the specified time from detection.	1	second
The system shall detect objects with the specified level of accuracy.	85	%
The system shall draw no more than the specified power.	20	Watts
The system shall produce a visible alert within the specified time from detection.	1	second
The system shall remain functional for the specified amount of time when not exposed to direct sunlight.	5	minutes
The system shall provide a total detectable range of the specified degree of the whole car.	180	degrees

Table #: Engineering requirement specifications for the performance and physical features of the envisioned system.

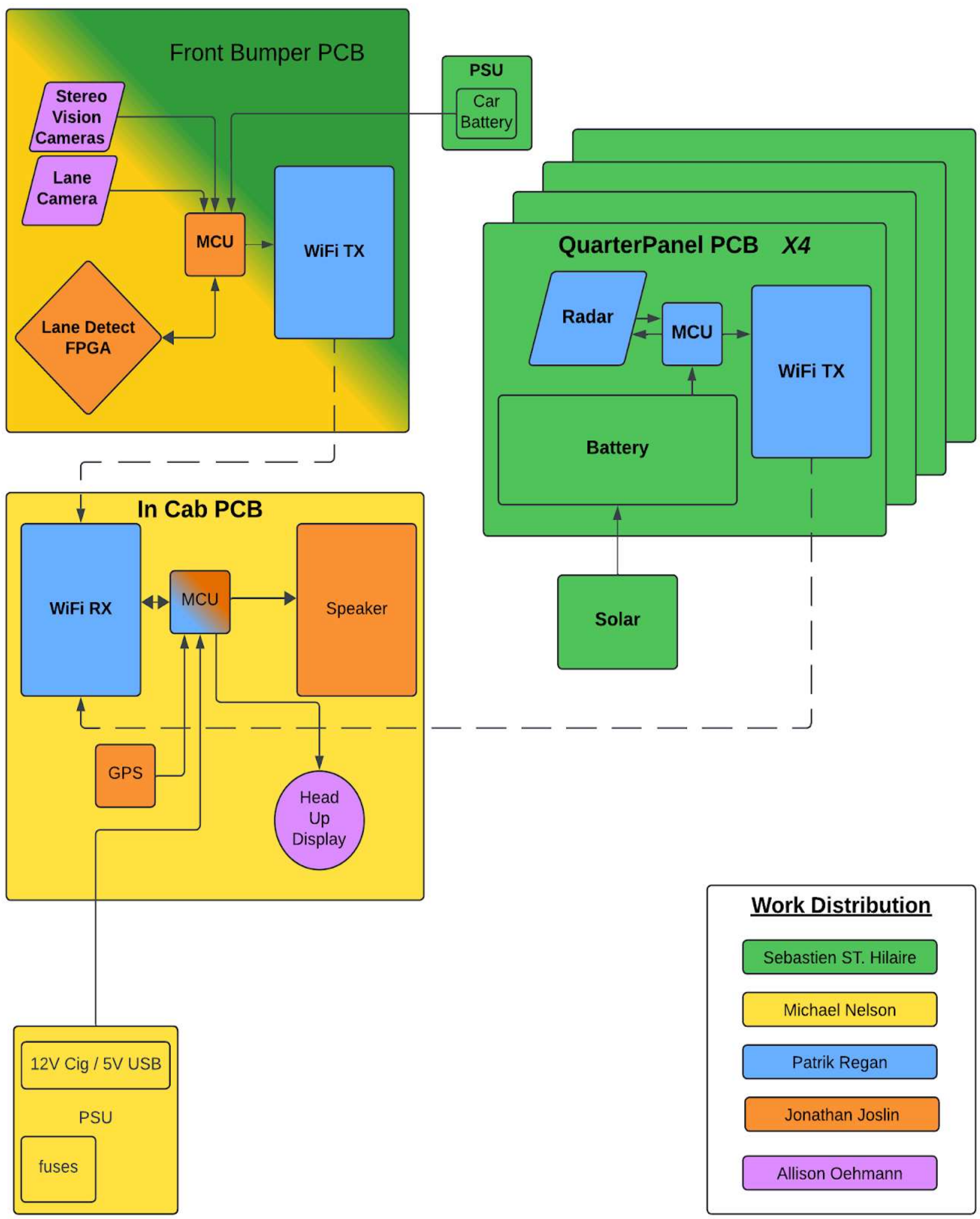
Component Performance Specifications

Component(s)	Parameter	Specification
Radar units	Detection range	2 meters
Front cameras	FOV	45°
Head up display	Image size	0.5 in^{2}.
Audio alert	Decibel magnitude	80 dB
Solar panel	Output power	20 W

Table #: Engineering requirement specifications for the components that will be used in this project to build the envisioned system.

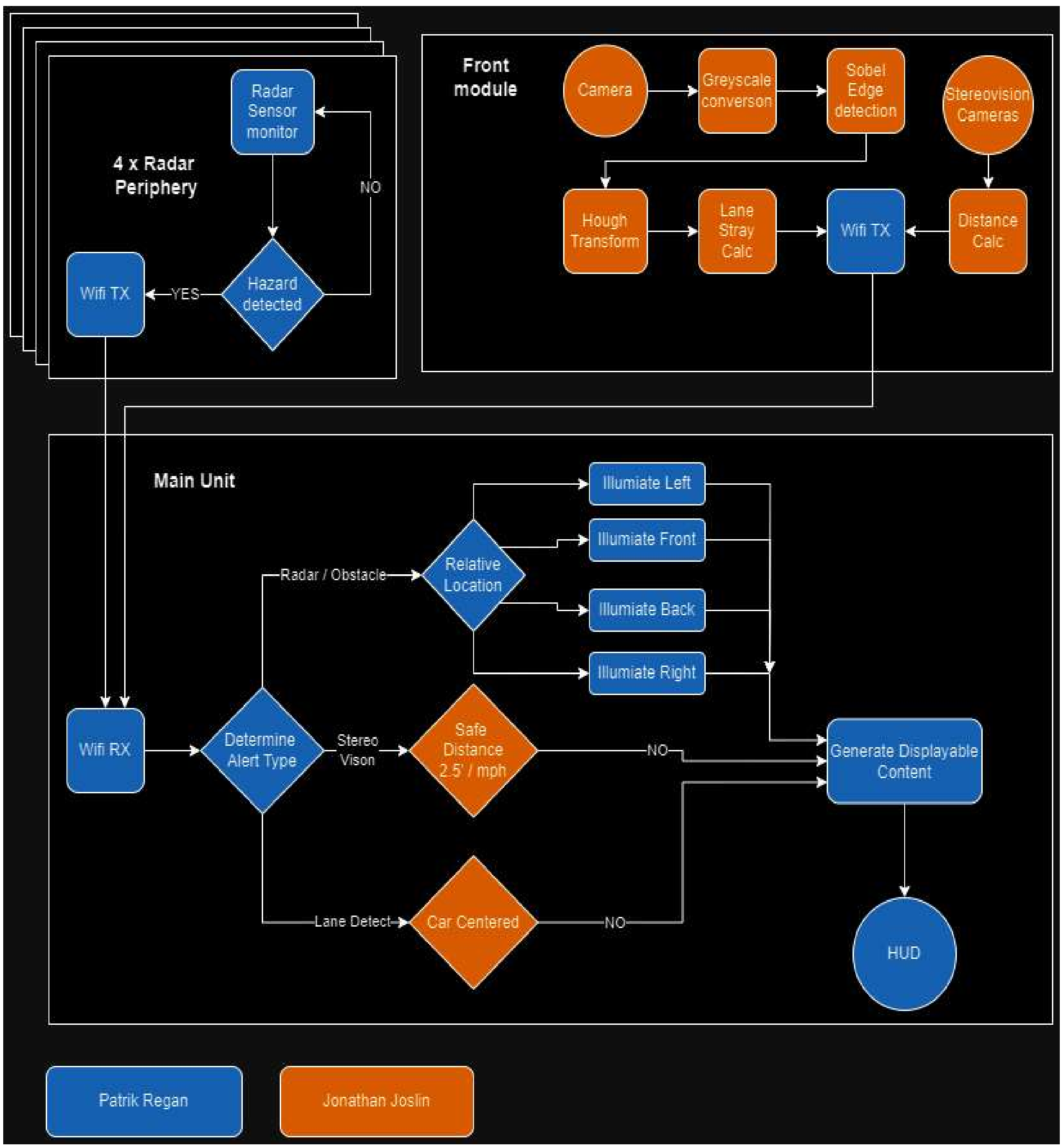
Hardware Block Diagram

The hardware block diagram illustrates the general system used to gather and present data for the vehicle operator. There are 5 wireless peripheries: four radar modules mounted on the quarter panels for blind spot detection. On the front bumper is a camera used for lane detection, and a system of two cameras used for stereo vision based distance calculation. Lenses used on cameras are to be optimized for purpose. Camera input for lane detention is sent to an FPGA logically programmed for lane detection processes such as Soble and hough transforms and CV. Work distribution is illustrated by a color coded key. Wireless peripheries are powered by dedicated batteries or attached to the car's battery. Solar panels are used to recharge dedicated batteries.

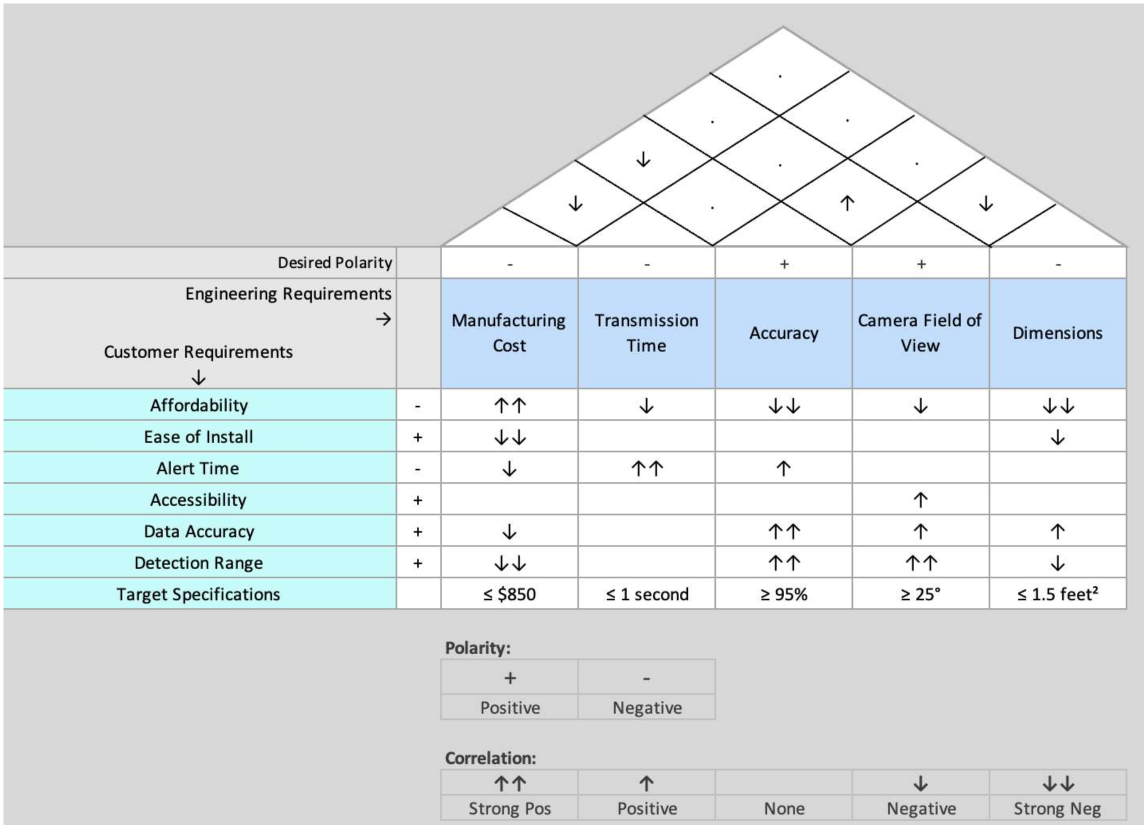


Software Diagram

With the software for this system, there are three different areas that will be worked on, the radar periphery, the front bumper module, and the main unit. With the software in the radar periphery, it will only be waiting for detection from a nearby obstacle, where it will then transmit to the main unit. With the front module, it will deal with software to detect if the driver is either straying out of their lane or if they are trailing behind the car in front of them too closely, then transmit it to the main unit. For the main unit, it will deal with software to determine what type of alert to send the user based on which peripheral sent the data.



House of Quality



Engineering Requirements → / Customer Requirements ↓		Manufacturing Cost	Transmission Time	Accuracy	Camera Field of View	Dimensions
Desired Polarity		-	-	+	+	-
Affordability	-	↑↑	↓	↓↓	↓	↓↓
Ease of Install	+	↓↓				↓
Alert Time	-	↓	↑↑	↑		
Accessibility	+				↑	
Data Accuracy	+	↓		↑↑	↑	↑
Detection Range	+	↓↓		↑↑	↑↑	↓
Target Specifications		≤ $850	≤ 1 second	≥ 95%	≥ 25°	≤ 1.5 feet^2

Polarity:

+	-
Positive	Negative

Correlation:

↑↑	↑		↓	↓↓
Strong Pos	Positive	None	Negative	Strong Neg

Milestones

Optical Fabrication Milestones

Task	Start Date	Anticipated End Date	Duration
Component Selection	9/6/2024	9/20/2024	2 weeks
Order Components	9/6/2024	9/20/2024	2 weeks
System Testing	9/20/2024	10/04/2024	2 weeks
Optical Midterm Demo	10/08/2024	10/08/2024	1 day
Finalize Design	10/08/2024	11/15/2024	5.5 weeks
Final Optical Demo	11/21/2024	11/21/2024	1 day

Project Fabrication Milestones

Task	**Start Date**	**Anticipated End Date**	**Duration**
Individual System Design	09/28/2024	10/26/2024	4 weeks
Individual System Testing	10/27/2024	11/17/2024	3 weeks
BreadBoard prototyping	10/21/2024	11/11/2024	3 weeks
Prototype Project Testing	11/11/2024	11/26/2024	2 weeks
PCB Design/ Ordering	11/12/2024	12/03/2024	3 weeks
PCB Testing	01/06/2025	TBD	TBD
System Testing	TBD	TBD	TBD
Practice Demo	TBD	TBD	TBD
Final Presentation	TBD	TBD	TBD

Project Documentation Milestones

Task	**Start Date**	**Anticipated End Date**	**Duration**
Brainstorming	08/20/2024	08/22/2024	2 Days
Divide and Conquer Document	08/22/2024	09/06/2024	2 Weeks
20 Page Milestone	09/06/2024	09/20/2024	2 Weeks
50 Page milestone	09/20/2024	09/27/2024	1 Week
75 Page milestone (Research and Investigation)	09/27/2024	10/11/2024 Due Date: 10/25/2024	2 Weeks
120 Page Milestone	10/11/2024	10/25/2024	2 Weeks

150 Page Milestone (Full report)	10/25/2024	11/12/2024 Due Date: 11/26/2024	2.5 Weeks

Financing

Budget

Description	Quantity	Budget
Radar	4	70
Camera	1	35
MCU	6	70
LaneDetect FPGA	1	55
GPS Module	1	10
HUD	1	200
WIFI Module	6	50
Speaker	1	5
PCB Board	6	195
Battery	4	80
Solar	4	60
Total		830

Proposed Bill of Material

Part Description	**Part**	**Quantity**	**Price**
Radar	AWRL1432BD	4	66.36
Camera	Arducam Me	1	34.99
MCU	MSP430F6459	6	67.29
LaneDetect FPGA	TBD	1	50.40
GPS Module	TBD	1	5.30
HUD	TBD	1	200.00
WIFI Module	ESP32	6	48.00
Speaker	TBD	1	5.00

PCB Board	TBD	6	195.00
Battery	MakerFocus	4	79.96
Solar	P124	4	55.80
		Total Cost:	**808.10**

Work Distribution Table

Electrical Engineering	
Sebastien St Hilaire	Front Bumper PCB
	Quarter Panel PCBs
	Solar Power
Michael Nelson	Main PCB unit
	Front Bumper PCB
Computer Engineering	
Patrik Regan	Radar Detection
	Local Wifi connections
Jonathan Joslin	Stereo Vision processing
	Lane Detection
	Audio Alert system
Optical Engineering	
Allison Oehmann	HUD design
	Camera lens designs

Appendix–A
Citations:

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2.) “Early estimate of motor vehicle traffic fatalities in 2023,” *Crash Stats NHTSA (Nation Highway Traffic Safety Administration)*, Apr. 2024. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813561#:~:text=A%20statistical%20projection%20of%20traffic,as%20shown%20in%20Table%201 (accessed Sep. 02, 2024).
3.) “U.S.: average selling price of new vehicles 2023 | Statista,” *Statista*, Jun. 19, 2024. https://www.statista.com/statistics/274927/new-vehicle-average-selling-price-in-the-united-states/#:~:text=In%20the%20United%20States%2C%20the,in%202023%20than%20in%202022
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8.) Wu, Wen & Blaicher, Fabian & Seder, Thomas & Cui, Dehua. (2009). A Prototype of Landmark-Based Car Navigation Using a Full-Windshield Head-Up Display System. 21-28. 10.1145/1631005.1631012.