The City College of New York, CUNY
Grove School of Engineering
Department of Electrical Engineering
160 Convent Ave, New York, NY 10031

EE 59868 - Senior Design I (Fall 2023)

Engineering Design Report

Blind Sight

(LIDAR Motorcycle Collision Avoidance System)

Submitted in partial fulfillment of
the requirements for the award of the degree of

Bachelor of Engineering
in
Computer and Electrical Engineering

Submitted by:

David Wang, Iftiak Ahmed, Kevin Campoverde, Li Ting Melisa Chen Chen.

Under the guidance of

Prof. Ping-Pei Ho, Prof. Edward Baurin

Date Submitted: Dec 13th, 2023

Chapter 1
Feasibility Study

1.1 Introduction

In an era of rapid urbanization, shifting consumer preferences, and the relentless pursuit of convenience, delivery apps have emerged as a transformative force, reshaping how goods and services reach our doorsteps. Digital platforms such as Doordash, Grubhub, and Uber Eats are powered by cutting-edge technology and an intricate network of couriers, have revolutionized the last-mile delivery industry and catalyzed a significant shift towards sustainable and efficient means of transportation [2].

One remarkable consequence of this technological evolution is the substantial increase in the use of bikes, motorcycles, and other one-rider vehicles as preferred delivery modes. The traditional internal combustion engine-based delivery fleets are slowly giving way to more agile, eco-friendly, and cost-effective alternatives[3].

The inclusion of bikes, motorcycles, and other single-rider vehicles introduces an elevated risk to their operators in the form of potential collisions with various obstacles, including other vehicles [1]. The implementation of a straightforward sensor designed to identify and lower the risk of collisions with other vehicles and other obstacles on the road., leveraging the advancements in LIDAR technology, holds the potential to avert such incidents. LIDAR's noteworthy utility lies in its ability to furnish precise data, which can be effectively processed and applied for enhanced safety measures. Expanding further on the concept of LIDAR, our focus is particularly on pulsed lasers. These pulsed lasers emit rapid bursts of light to swiftly assess the objects in the path ahead. Our product will be designed to be practical and accurate for the riders.

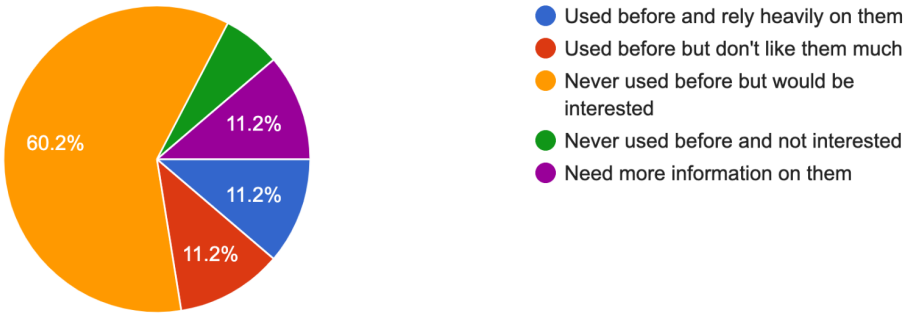
1. Cosimo Lucci, Trevor Allen, Niccolò Baldanzini & Giovanni Savino. (2022) Motorcycle curve assist A novel approach based on active speed control for crash injury reduction. Traffic Injury Prevention 23:sup1, pages S56-S61.
2. Ahuja, K., Chandra, V., Lord, V., & Peens, C. (2021, September 22). *Ordering in: The rapid evolution of food delivery*. McKinsey & Company.
3. *Motorcycles - Injury Facts*. (2023, April 25). Injury Facts.

1.2 Need and Market Research

To better understand the needs of our target audience, we decided to conduct a questionnaire on various motorcycle forum groups to determine the functionality of our product. From surveying a community of motorcyclists, our team received the following responses that provided valuable additional insights into the need for our product.

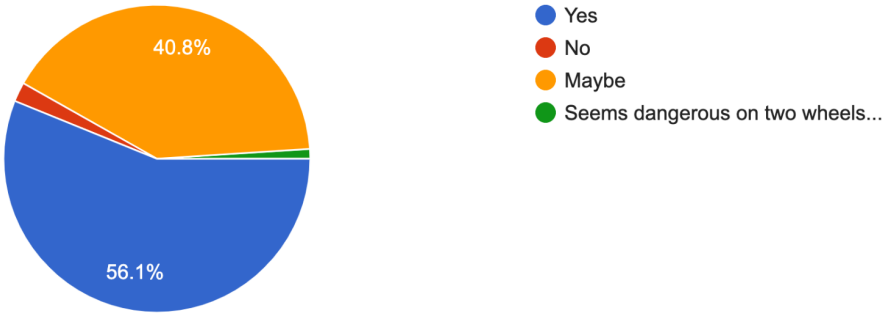
How do you feel about Collision Alert Systems and have you ever used such devices to help you better navigate the roads?

98 responses



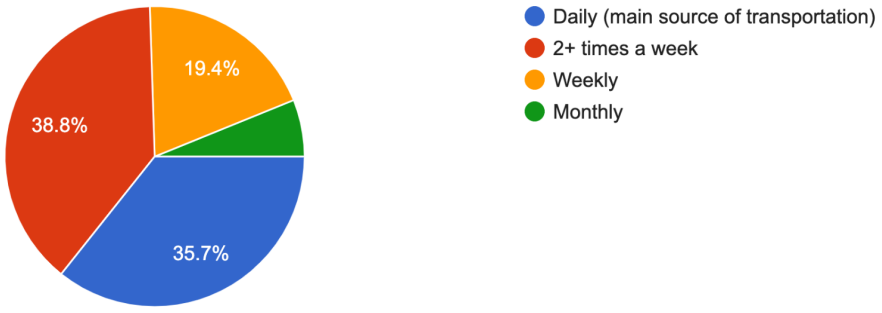
Are you open to trying our Collision Alert System ?

98 responses



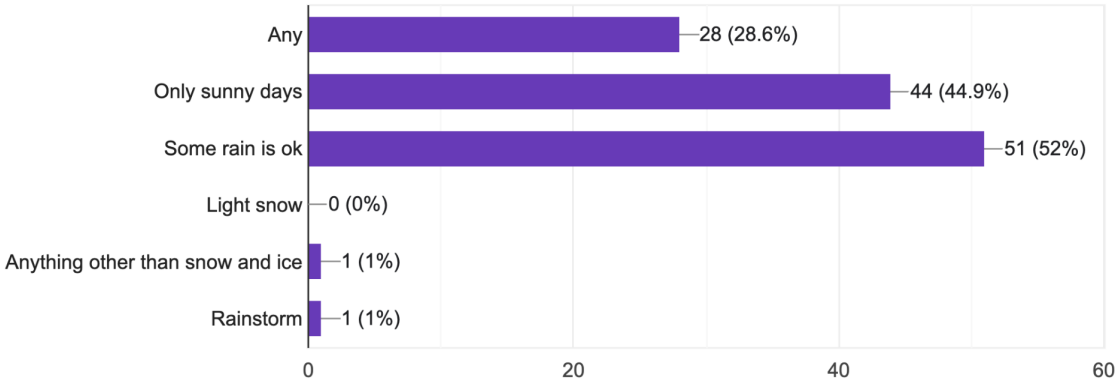
How often do you ride your vehicle?

98 responses



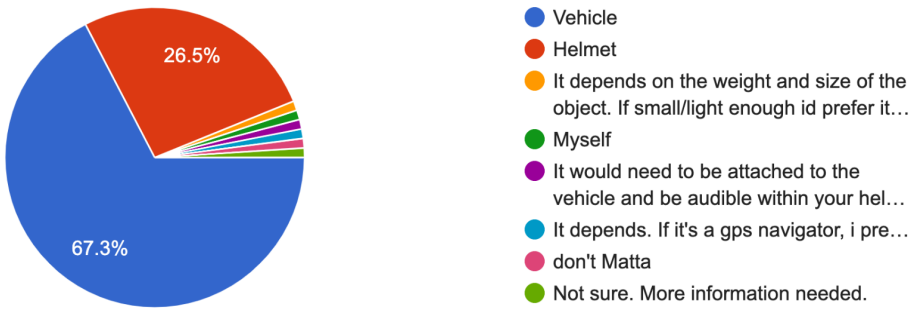
What type of weather do you mainly ride in?

98 responses



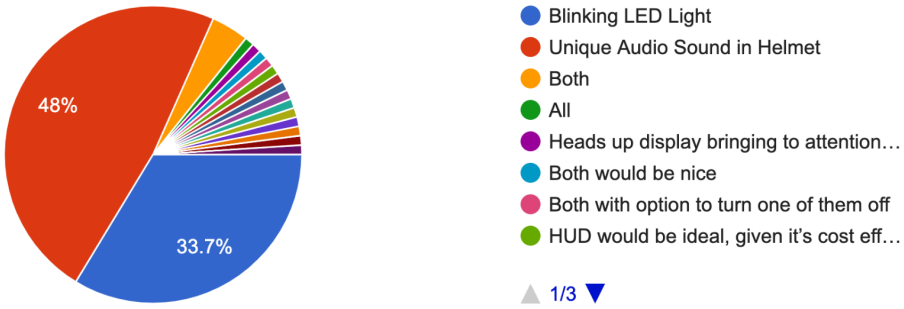
Would you prefer the device attached to the helmet or your vehicle?

98 responses



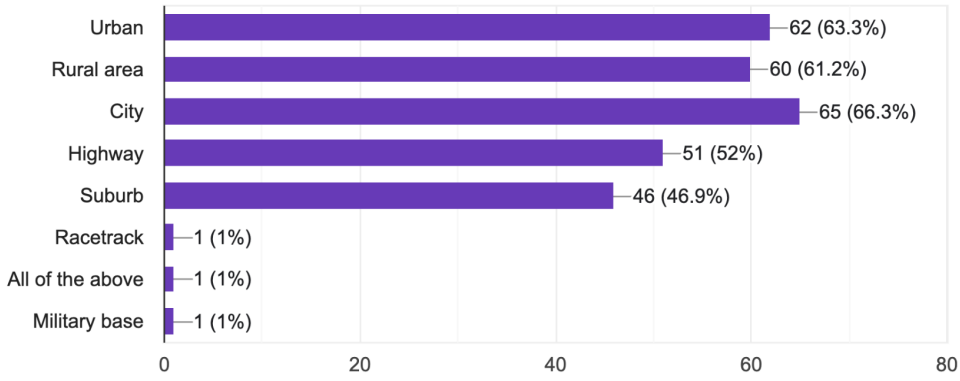
How would you like the device to alert you of an obstacle or hazard?

98 responses



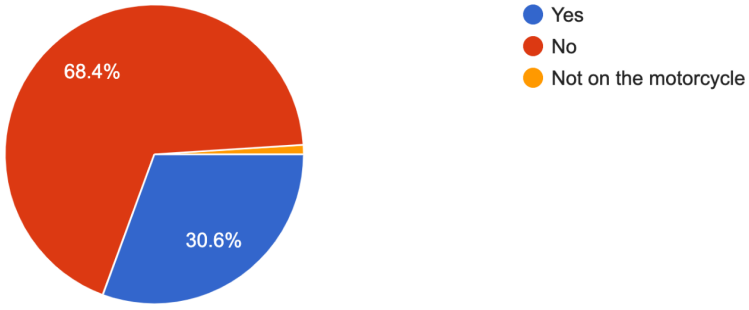
What type of areas do you drive most often in?

98 responses



Have you ever been involved in an accident?

98 responses



The growing market of food delivery services, like Doordash, Grubhub, and Uber Eats, has led many drivers to choose bikes, e-bikes, motorcycles, or other two-wheel vehicles for delivering food to customers. According to a CNN business report [**1**], an estimated 80% of delivery workers rely on e-bikes and motorbikes, and around 65,000 delivery workers on UberEats, DoorDash, Postmates, and other apps who bike around the city's five boroughs every day, pushing to bring impatient customers their meals as quickly as possible. This expansion of the market has increased the presence of two-wheel vehicles on the road, alongside traditional automobiles. According to Bureau of Transportation statistics "from March 2020 (the first month of the COVID-19 national emergency) to March 2023 (the latest available data), bike spending has increased 620%, adjusted for inflation. In the last year, total national household expenditures on bicycles and accessories have remained around $8.0 billion per month" [**2**].

Companies like the Forcite Helmets, in collaboration with the University of Canberra, Macquarie University, and Western Sydney University, spearhead the development of cutting-edge smart helmets and sensing technology. This collaborative initiative has received crucial support in the form of a $1,650,505 research grant from the Federal Government. The comprehensive project, valued at $5,654,275 in total, has attracted key partners, including Transport for NSW, APPRO Photoelectron Inc., NSW Smart Sensing Network (NSSN), and Harley Davidson Australia, working together to drive innovation in this field as stated in the article [**3**].

Another player in the development of the driver assistance system is Bosch Mobility. Bosch Group's biggest business sector is Mobility, boasting a 2022 sales figure of 52.6 billion euros,

which accounts for nearly 60 percent of the total sales. This positions the Bosch Group as a prominent player among automotive suppliers. The Mobility sector is driven by a vision of safe, sustainable, and thrilling mobility [**4,5**].

In 2025, the worldwide motorcycle Advanced Driver Assistance Systems (ADAS) market boasted a valuation of $1.86 billion. Projections indicate a substantial growth trajectory, with an estimated value of $3.34 billion by 2035. This anticipated expansion is set to unfold at a compound annual growth rate (CAGR) of 6.3% from 2026 to 2035 [**6**].

In addition, upon visiting various motorcycle rider forums, we discovered that similar collision prevention devices had been used by some riders (one example of a rider who used lane laser lights behind his motorcycle to alert drivers of his presence). The comments on the forums suggest that many riders would be open to the idea of purchasing such devices, however many raised concerns about the functionality aspect of the device. It must be made clear that our device will be marketed as an assist in collision prevention. It will be a cheaper alternative without even sacrificing a safety feature and is compact.

1. Meyersohn, N. (2023, May 5). *How on-demand delivery services hobbled an American city | CNN Business*. CNN. How on-demand delivery services hobbled America's biggest city | CNN Business

2. Bureau of Transportation Statistics. *Notable for Bike To Work Week: National Spending on Bicycles and Accessories Grew 620% from March 2020 to March 2023; Docked Bikeshare Grew 42% percent*. (n.d.). https://www.bts.gov/data-spotlight/notable-bike-work-week-national-spending-bicycles-and-accessories-grew-620-march

3. Forcite Helmet Systems. *Forcite Helmets*, www.forcitehelmets.com/en-us/blog/revolutionising-motorcycle-safety/..

4. "Smart Driver Assistance Systems." *Smart Driver Assistance Systems*, www.bosch-mobility.com/en/mobility-topics/adas/.

5. Advanced Rider Assistance Systems." *Bosch Mobility*, www.bosch-mobility.com/en/solutions/assistance-systems/advanced-rider-assistance-systems-2w/#:~:text=In%20road%20traffic%2C%20even%20the,or%20to%20mitigate%20its%20consequences.

6. *Motorcycle ADAS Market Trends, Analysis, Size, Share by 2035*. (n.d.). Allied Market Research. https://www.alliedmarketresearch.com/motorcycle-adas-advanced-driver-assistance-system-market-A07159

1.3 Problem

Our central challenge is to enhance the safety of bike, motorcycle, and single-rider vehicle operators by providing an affordable, easy-to-use, and accurate device for the user. The primary obstacle is designing a reliable low-cost device that won't divert drivers' attention from potential road hazards. Our device must work seamlessly, even in challenging situations, alerting the driver when necessary to avoid distractions that could lead to accidents. To address these concerns, we are employing LIDAR technology to ensure the utmost safety through highly accurate information provided by our sensors. A secondary challenge is ensuring that our device is easy to use, inconspicuous, preventing overreliance on the technology, and activating effectively only when needed by the rider.

1.4 Requirements

There will be two types of requirements that will be discussed, external and internal requirements. External requirements are the needs of a potential customer while internal requirements are the expectations of the stakeholders and team members

1.4.1 External Requirements

The external requirements of our product are that our customers will need to own a bicycle, motorcycle, or any single-ride vehicle that is allowed on the road. The product will be an attachment to their vehicle and provide instant analysis of the surrounding area to aid our users in avoiding a collision incident. We will be using the TF Luna LiDAR Module as our sensor and its specifications can be found below.

TF Luna LiDAR Module Specifications:

Product Performance:

Operating Range	0.2m~8m (90% Reflectivity indoor)
	0.2m~2.5m (10% Reflectivity indoor)
	0.2m~8m (90% Reflectivity outdoor)
	0.2m~2.5m (10% Reflectivity outdoor)
Accuracy	± 6cm @(0.2m-3m)
	± 2% @(3m-8m)

Distance Resolution	1cm
Frame Rate	1-250 Hz
Ambient Light Immunity	70Klux
Operation Temperature	(-10°C) ~ (60°C)

Optical Parameters:

Light Source	VCSEL
Central Wavelength	850nm
Photobiological Safety	Class 1 (IEC60825)
FOV	$2^{\circ 5}$

Electrical Parameters:

Supply Voltage	3.7V - 5.2V
Average Current	≤ 70mA
Power Consumption	≤ 0.35W
Peak Current	150 mA

Communication Level	LVTTL (3.3V)
Communication Interference	UART/12C

Others:

Dimensions	35mm*21.25mm*12.5mm (L*W*H)
Housing	ABS + PC
Storage Temperature	-20°C ~ 75°C
Weight	<5g

1.4.2 Internal Requirements

The following are our internal requirements:

1.4.2.1 Market

Our product is high in demand for an individual who utilizes motorcycles, bicycles, and other single-ride vehicles. With the growing use of these vehicles on the road, it is imperative that people remain safe on the road. Our product will provide individuals with an affordable tool to remain safe on the road and easy to use to make up for any blind spots that they may possess.

1.4.2.2 Competition

In the current market, several options are available, including Ride Vision 2, KiWAV BSDII Blind Spot Detection System With LED Indicators 79GHz (**1**), and the Forcite Smart Helmet. Ride Vision 2 and the KiWAV system are designed as attachments for motorcycles. At the same time, the Forcite Smart Helmet integrates the detection system with various other features that bikers may desire in a helmet.

Figure: Forcite Smart Helmet

The Ride Vision 2 with its detection system and LED lights costs up to $700 for a biker **(2**). The KiWAV BSDII Blind Spot Detection System With LED Indicators 79GHz costs up to $550. Finally, the Forcite Smart Helmet costs up to $1000.

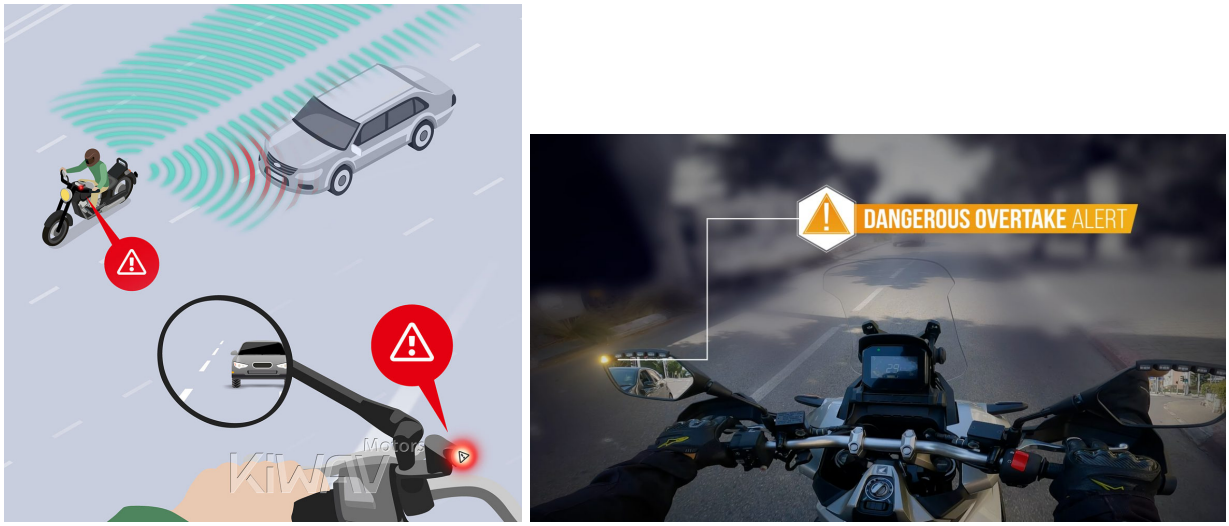


Figure: KiWAV and Ride Vision 2

Source:

1. Andrew, et al. “BSD LCA Mirrors: BSDII Blind Spot Detection System with LED Indicators 79GHz BSD Blind Spot Detection LCA Lane Change Assist.” *KiWAV Motors*, kiwavmotors.com/en/mirrors/bsd-lca-mirrors/bsdii-blind-spot-detection-system-with-led-indicators-detail.

2. *Ride Vision 2 Pro - Ride Vision*. (2023, October 1). Ride Vision.

1.4.2.3 Time to Market

Our project will produce a working prototype that is ready for testing by May 2024.

1.4.2.4 Niche

Our product is only designed for bikers, thus the motorcycle industry. It is supposed to be used only on roadways. This product can be modified for use in other vehicles, the current focus is only motorcycles.

1.5 Limitations

To maintain the safe use of the LiDAR Laser the following warning must be acknowledged:

1. Avoid direct exposure of human eyes to laser light. May result in Eye damage.
2. Never point the laser light at another person.
3. Keep the laser-equipped unit out of the reach of children.

There will be two types of requirements that will be discussed, external and internal requirements. External requirements are the needs of a potential customer while internal requirements are the expectations of the stakeholders and team members

1.5.1 Regulations

- Exploring Bicycle Options for Federal Lands: Bike Sharing, Rentals, and Employee Fleets

Transportation Department. Federal Highway Administration. 2012.

https://www.govinfo.gov/content/pkg/GOVPUB-TD2-PURL-gpo41987/

Federal land management agencies are exploring how bicycle programs can provide employees and visitors with more travel choices while working toward their environmental, public health, and sustainability goals. This report explores three options for making bicycles more readily available in Federal lands: public bicycle-sharing programs, bicycle rental operations, and employee bicycle fleets. Bicycle-sharing programs are a form of public transportation, supplying bikes for short-term use through a network of automated bike parking stations. Bike rental programs are typically for-profit businesses that rent bikes for recreational use for a few hours up to several days. Employee fleets make bikes available to individuals associated with an

organization to use for work, errands, and/or recreation, usually at no cost. This report builds on previous work from The Guide to Promoting Bicycling on Federal Lands (FHWA, 2008a), which sought to raise awareness of the environmental, public health, and resource management benefits of bicycling. This report presents various methods to make bikes more available in Federal lands through bike-sharing programs, rentals, and employee fleets. This report explores how elements of successful bike programs may be adapted for Federal lands settings.

- Code of Federal Regulations Title 21 - Food and Drugs Chapter - Subchapter J - RADIOLOGICAL HEALTH, Part 1040 - PERFORMANCE STANDARDS FOR LIGHT-EMITTING PRODUCTS, Section 1040.10 - Laser products.

https://www.govinfo.gov/app/details/CFR-2000-title21-vol8/CFR-2000-title21-vol8-sec1040-10

(i) Is accompanied by a general warning notice that adequate instructions for the safe installation of the laser product are provided in servicing information available from the complete laser product manufacturer under paragraph (h)(2)(ii) of this section, and should be followed,

- The Laser Product Performance Standard of the Center for Devices and Radiological Health (21CFR 1040.10 and 1040.11) (Code of Federal Regulations)

The Laser Product Performance Standard of the Center for Devices and Radiological Health (21CFR 1040.10 and 1040.11) pertains to our product because we will be heavily relying on the use of lasers. This section entails the importance of labeling and describing the parameters of the lasers used in the device. Labels must include the spectrum of wavelengths the laser will emit, the amount of radiation emitted, along with other important user information

(A statement of the magnitude, in appropriate units, of the pulse durations(s), maximum radiant power, and the maximum radiant energy per pulse of the accessible laser radiation, etc.). It must also be labeled with the proper class type of laser with its corresponding warning logotype. Easily accessible and noticeable with proper description.

We must make sure our product meets the general standards of electronic devices. The laser is only a small portion of our device. We will be also working with electronic parts such as the switching gain and photodetector, etc. Our device will have to ensure general safety for the consumer/user of our device (Scope, Certification, Identification, Variances, etc.)

1.5.2 Standards

- The American National Standards Institute (ANSI Z136 Series)

The American National Standards Institute (ANSI Z136 Series) provides guidance for the safe use, maintenance, service, and installation of optical communications systems utilizing laser diodes or light-emitting diodes that operate at wavelengths between 0.6 mm and 1 mm. This will be useful for the safety of our device and the safety of the user. It will also be useful for our team as we develop our laser to run at specific parameters (850 nm wavelength).

- IEC; Geneva, Switzerland: 2014. Safety of Laser Products—Part 1: Equipment Classification and Requirements. [Google Scholar]

IEC 60825-1:2014 is applicable to the safety of laser products emitting laser radiation in the wavelength range of 180 nm to 1 mm. A laser product may consist of a single laser with or without a separate power supply or may incorporate one or more lasers in a complex optical, electrical, or mechanical system. Typically, laser products are used for demonstration of physical and optical phenomena, materials processing, data reading and storage, transmission and display of information, etc. Such systems have found use in industry, business, entertainment, research, education, medicine, and consumer products. Laser products that are sold to other manufacturers for use as components of any system for subsequent sale are not subject to IEC 60825-1, since the final product will itself be subject to this standard. Laser products that are sold by or for manufacturers of end products for use as repair parts for the end products are also not subject to IEC 60825-1. However, if the laser system within the laser product is operable when removed from the end product, the requirements of Part 1 apply to the removable laser system. The objectives of this part of IEC 60825 are:

- To introduce a system of classification of lasers and laser products emitting radiation in the wavelength range 180 nm to 1 mm according to their degree of optical radiation hazard to aid hazard evaluation and to aid the determination of user control measures;
- To establish requirements for the manufacturer to supply information so that proper precautions can be adopted;
- To ensure, through labels and instructions, adequate warning to individuals of hazards associated with accessible radiation from laser products; and

- To reduce the possibility of injury by minimizing unnecessary accessible radiation and to give improved control of the laser radiation hazards through protective features. This edition includes the following significant technical changes with respect to the previous edition:
- A new class, Class 1C, was introduced;
- The measurement condition 2 ("eye loupe" condition) was removed;
- A classification of the emission of laser products below a certain radiance level that are intended to be used as a replacement for conventional light sources can, as an option, be based on the IEC 62471 series;
- And the accessible emission limits (AELs) for Class 1, 1M, 2, 2M and 3R of pulsed sources, particularly of pulsed extended sources, were updated to reflect the latest revision of the ICNIRP guidelines on exposure limits (accepted for publication in Health Physics Journal 2013, see also www.icnirp.org).
- IEC; Geneva, Switzerland: 2016: ISO TS 19159-2: Geographic information - Calibration and validation of remote sensing imagery sensors and data - Part 2: Lidar

This part of ISO/TS 19159 defines the data capture method, the relationships between the coordinate reference systems and their parameters, as well as the calibration of airborne lidar (light detection and ranging) sensors.

This part of ISO/TS 19159 also standardizes the service metadata for the data capture method, the relationships between the coordinate reference systems and their parameters and the

calibration procedures of airborne lidar systems as well as the associated data types and code lists that have not been defined in other ISO geographic information international standards.

1.5.3 Patents

There are several patents that have been issued for similar products, their full documents can be found in the appendix.

- Motorcycle Blind Spot Detector *(United States Patent - Lunsford)*

The present invention relates to an electronic device for monitoring the blind spot of a motorcycle driver. The device includes a lean detector to incorporate lean into the position of the motorcycle driver.

- Vehicular Collision Avoidance System*(United States Patent - Wolf)*

A vehicular collision avoidance system includes a forward-viewing camera, a rearward-viewing camera, a rearward-sensing non-vision sensor, and an electronic control unit. The vehicular collision avoidance system detects vehicles present forward and/or rearward of the equipped vehicle. Responsive to at least one selected from the group consisting of (i) data processing of image data captured by the rear-ward-viewing camera and (ii) data processing of sensor data captured by the rearward-sensing non-vision sensor, the vehicular collision avoidance system detects another vehicle approaching the equipped vehicle from the rear, determines that the other vehicle is traveling in the same traffic lane as the equipped vehicle, determines speed difference between the vehicles, and determines the distance from the equipped vehicle to the other vehicle. Based on such determinations. the system determines that impact with the equipped vehicle by the other vehicle is imminent.

- Vehicular Collision Mitigation System *(United States Patent - Salomonsson et al.)*

A collision mitigation system for a vehicle includes a plurality of cameras, a radar sensor and/or lidar sensor, and a control that may process data captured by the cameras, radar sensor and/or lidar sensor. When the vehicle is moving and responsive at least in part to a determination that the vehicle is approaching an object present forward of the vehicle, the control is operable to control application by an automatic emergency braking system of a vehicle brake of the vehicle to mitigate collision with the object. Responsive to the determination that a following vehicle is following the vehicle and when the determined following vehicle is within a threshold distance from the vehicle and is approaching the vehicle above a threshold rate of approach, the control adjusts automatic emergency braking of the vehicle to mitigate collision at the rear of the vehicle by the determined following vehicle

1.5.4 Safety

The lab safety training was provided by the Lab Technician, David Santoro, in the Senior Design laboratory at City College, where we watched three different DVDs about lab safety. Based on the training, we comply with the following safety rules set by the department.

1.5.4.1 Lab Safety

The lab safety rules were posted in the senior design lab. While working in an electrical design, we'd deal with several wiring and power equipment. It is crucial for our safety that we understand how electricity works. For instance, the household operating voltage is 120V. We need to operate our equipment with this voltage to avoid any damage. The following are some of the safety rules we followed inside the lab.

1. High intensity of current causes injury. Therefore, we must be aware of the current intensity we're dealing with.

2. Switch and grounding in the circuit should be properly regulated.

3. Safety work practices must be followed to avoid hazards such as fire, shocks, and burns.

4. Faulty wires should be disposed of to avoid short circuits and electric shocks.

5. The extension cord should not be overloaded with high loads.

6. Electrical equipment and flammables should always be double insulated.

7. Water and liquids should be prevented in the lab.

8. In case of emergencies, we should cut off the electricity.

9. First aid should be provided to injuries and emergency officers should be immediately called.

10. In case of choking, CPR should be given to the patient.

11. Type C fire extinguishers should be used in case of firing.

1.5.4.2 LASER and Sensors Handling

Although we would not deal with lasers for our prototype development, it's crucial to understand the severity of lasers and how to handle them. For our product, we'd use Radar, which is a type of sensor. Understanding how lasers and sensors work in general will help us in our safety. The following protocols should be followed while handling lasers.

1. We should follow the safety rules of the Laser Institute of America.

2. Depending on the classes of lasers, the safety manual of the laser should be read to avoid dangers if any.

3. Some laser-generated air can be dangerous and can cause erythema and skin cancer. So we should wear proper PPE inside laser labs.

4. In engineering, the Standard Operating Officer establishes the laser control measures, which should be followed.

5. Compressed and staged gas should be handled with care under supervision.

6. When using laser equipment, a notice of being used should be posted outside the door to inform others that the instrument is being used to ensure the safety of others.

7. One should not point a laser at others.

8. If there is any emergency situation, the machines should be turned off immediately.

9. A professional's help should be requested if one is unable to determine whether the situation is safe and feels that it cannot be handled.

1.6 Constraints

Our project has the following constraints

- Time: Eight Months (Sept 4th, 2023 - May 15th, 2024)
- Limited Knowledge: Since our team mostly consists of Computer Engineer undergraduate students, our knowledge of photonics is limited.
- Financial: With the high cost of LIDAR sensors, we need to properly determine the range of our sensors that will fit within our budget.

1.7 Primary Stakeholders and Roles

Prof. Ping-Pei Ho - Project Advisor/Sponsor

Prof. Edward Baurin - Project Management Advisor

David Wang - Project Manager

Iftiak Ahmed - Project Member

Kevin Campoverde - Project Member

Li Ting Melisa Chen Chen - Project Member

1.8 Project Charter

Date: Oct 1st, 2023

Project Name: Blind Sight (LIDAR Motorcycle Collision Avoidance System, LIDAR M-CAS)

Project Manager: David Wang

Project Justification (problem or opportunity addressed):

Our project will provide another tool for bikers to avoid dangers on the road.

Specific Project Objectives & Success Criteria(schedule, cost, quality):

We aim to create a device that utilizes a LIDAR sensor to detect vehicles that may collide with the host user, the sensor data will then run through an algorithm to determine whether or not a warning needs to be provided to our user. Our objective is to finish this project by May 15th, 2023, while staying within the assigned budget of $250. The success of our project will be determined if our product can accurately detect a vehicle that might collide with our user and will properly warn our user when so.

Primary Stakeholders & Roles (including a broad statement of roles and responsibilities of all customers, sponsors, contributors, reviewers, managers, sign-off authorities, project manager, etc.):

Professor Ho, affiliated with the Electrical Engineering department at the Grove School of Engineering at The City College of New York, and Professor Baurin, higher education officer and faculty advisor for the Electrical Engineering department at the Grove School of Engineering

at The City College of New York, are mentoring us in project development and project management respectively. The mentors will review the results of our product.

Key Assumptions(including a broad statement of sponsor/stakeholder inputs and resources to be provided, as well as a delineation of "what's outside" project scope):

Professor Ho, a sponsor, supplied us with previous Senior Design project material that is pertaining to the subject. All team members, also considered stakeholders, will contribute to the project as human resources. This encompasses a comprehensive overview of sponsors and stakeholder input and resources to be furnished, along with a clear distinction of the aspects that fall beyond the project scope.

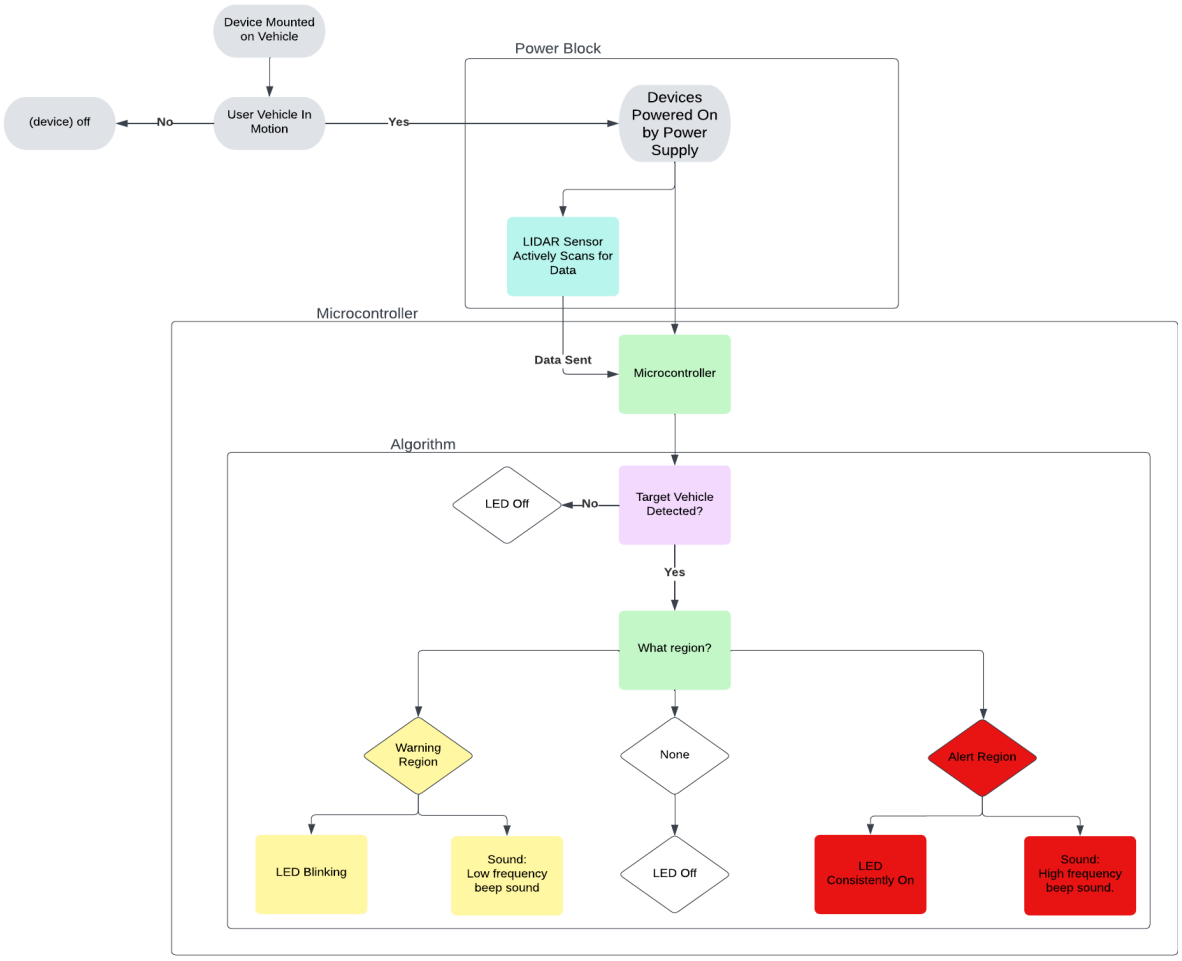
Signatures: The following people agree that the above information is accurate:

Project Team Members: David Wang, Iftiak Ahmed, Kevin Campoverde, Li Ting Melisa Chen Chen.

Project Sponsor and/or authorizing Manager(s): Prof. Ping-Pei Ho, Prof. Edward Baurin

Chapter 2
Plan

2.1 Product Block Diagram



2.2 Scope of Project

Motorcyclists face many dangers on the road that can lead to fatal accidents, especially from drivers of other vehicles. The scope of this project is to build a device that will assist a motorcyclist in avoiding a potential collision with another vehicle on the road.

2.2.1 Boundaries

Ideally for our project, we would like to have a 360° FOV warning device. According to the data received from our market research, we would also want to include both an LED HUD (heads-up display) and an audio warning device. Unfortunately due to financial and time constraints, we had to set certain boundaries for our product. Instead of having a 360° FOV, the device will detect a rear-moving vehicle with a 180° FOV and provide the motorists with an alert via an LED light mounted on the motorcycle and an audio alert as well. Unfortunately, we are unable to provide a HUD for our product as this will put us well out of our budget therefore our visual warning will be two LED lights mounted on either side of the motorist's handlebars. The audio warning will be a simple “beeping” noise to give the rider not only a visual warning but an audio one as well.

2.2.2 Deliverables

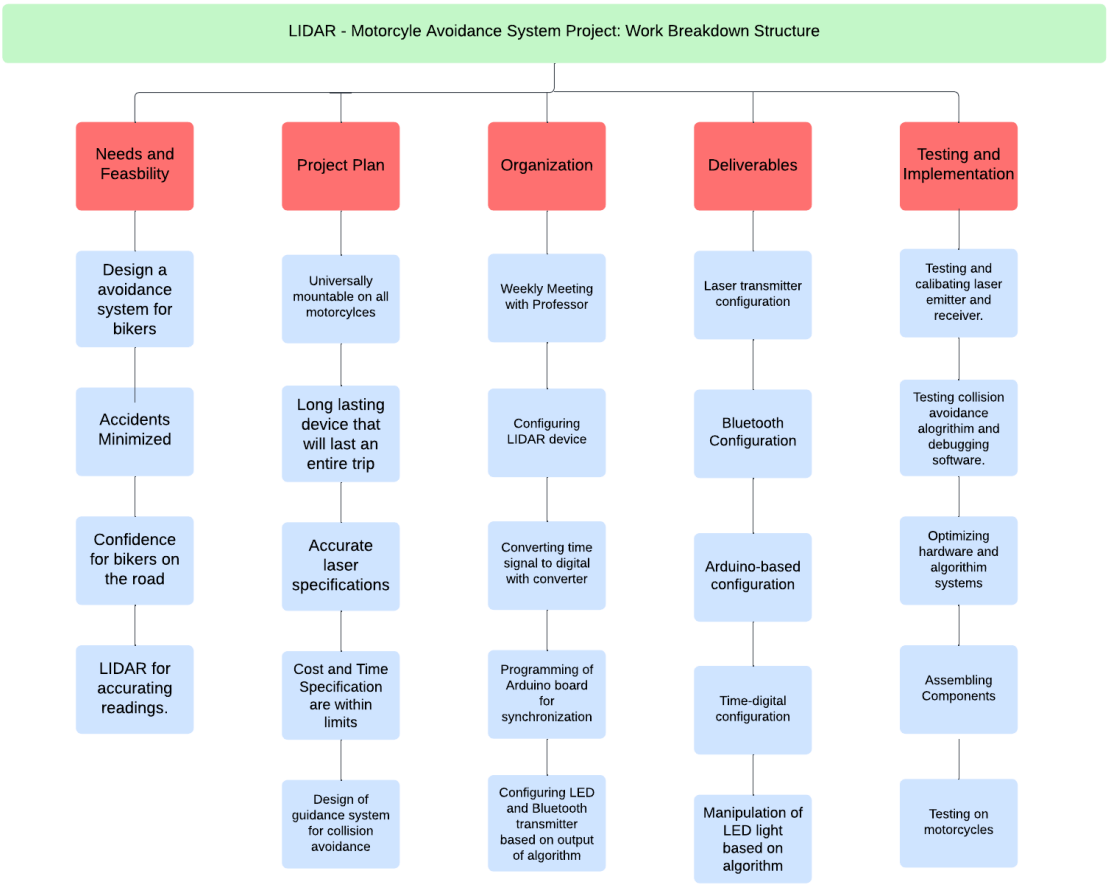
Here is a list of all our deliverables for our project except minuscule components such as resistors, jumper cables, etc.:

- LED light sitting on the handlebars or mirrors of the motorcycle
- Power supply drawing power from the battery of vehicle
- Housing component that will hold the other devices in place
- TF Luna LiDAR module sitting in the housing component
- Bluetooth transceiver module connected to the microcontroller.

- Arduino microcontroller sitting in the housing component.
- Headset speaker mounted to the helmet of the rider.
- All of the components connected to the PCB Board

If at any point our project scope changes, we will discuss the issues as a group and readjust our scope. We will have weekly meetings throughout the building phase of our project and we will also construct progress reports to monitor any necessary adjustments to our project scope.

2.3 Work Breakdown Structure



2.4 List of Activities

Each major deliverable from the work breakdown structure is further simplified into the following list of activities.

2.4.1 Feasibility

- Research Review.
- Create a strategy for the project.
- Evaluate and produce a list of criteria for success.
- Identify how to improve or utilize previous projects.
- Generate project introduction.
- Generate project description.
- Generate project charter.
- Identify competitors.
- Identify internal and external requirements.
- Complete documentation of all necessary aspects related to feasibility.

2.4.2 Planning

- Identify stakeholders
- Identify deliverables.
- Generate project scope.

  Generate planning figures.
- Plan out schedule and budget.
- Generate a 3D model mockup for the housing unit for the microcontroller and sensor.

- Create pseudo code for the algorithm to detect vehicles in blindspots as well as an avoidance prevention system.
- Create a circuit design to interconnect all hardware components.

2.4.3 Design

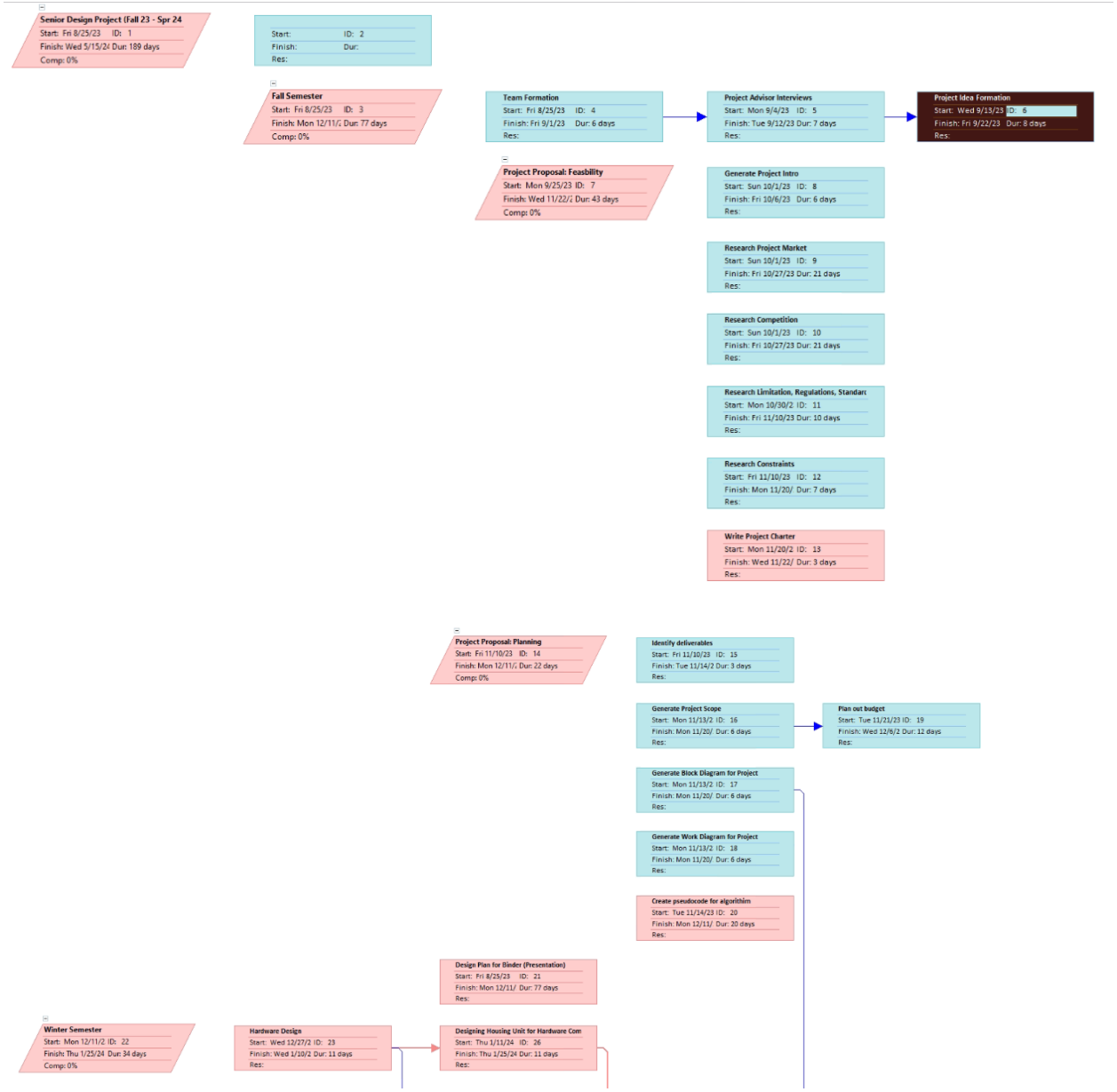
- Obtain all hardware components.
- Test hardware components.
- Implement hardware design.
- Understand and test algorithms in a controlled environment.

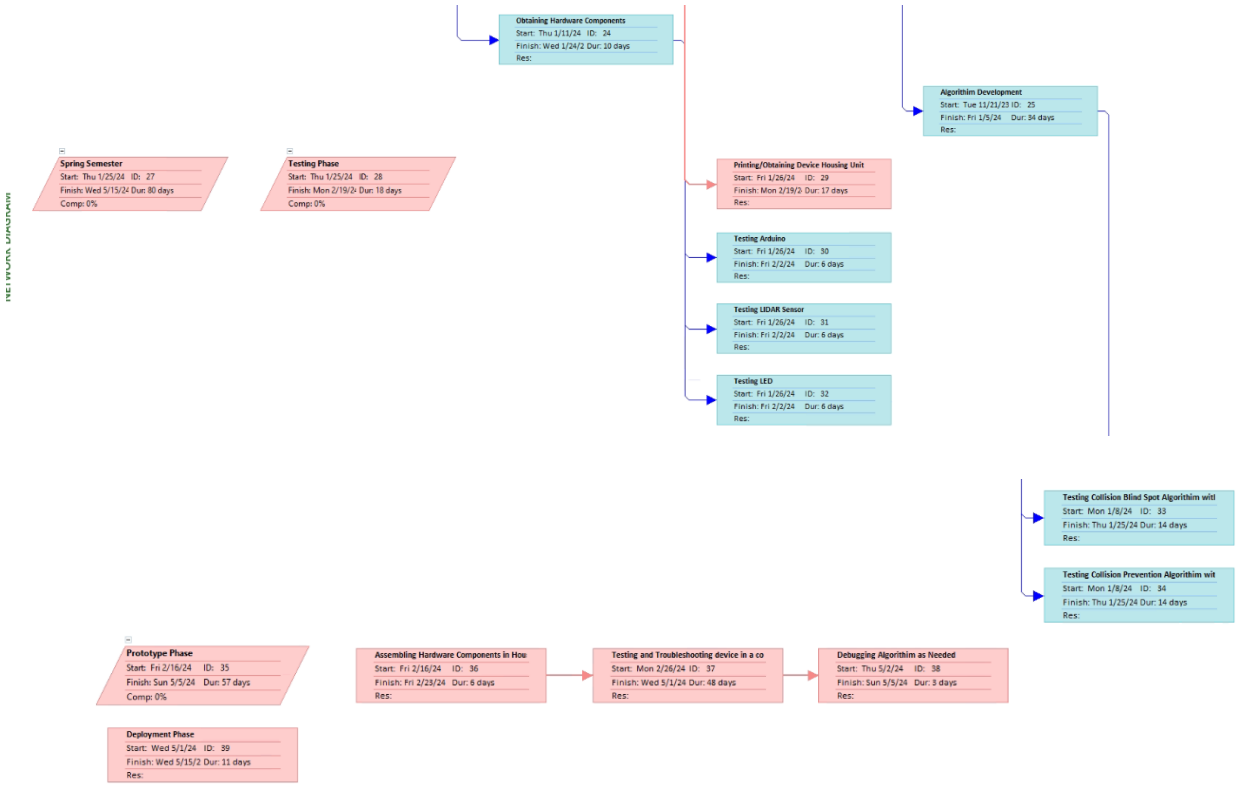
2.4.4 Prototype

- Assemble hardware components into a prototype.
- Test prototype in a controlled environment utilizing motor vehicle assets that belong to stakeholders.
- Debug any issues that may come from prototyping.
- Create a market design.
- Compile all relevant documents into formal documentation.

2.4.5 Deployment

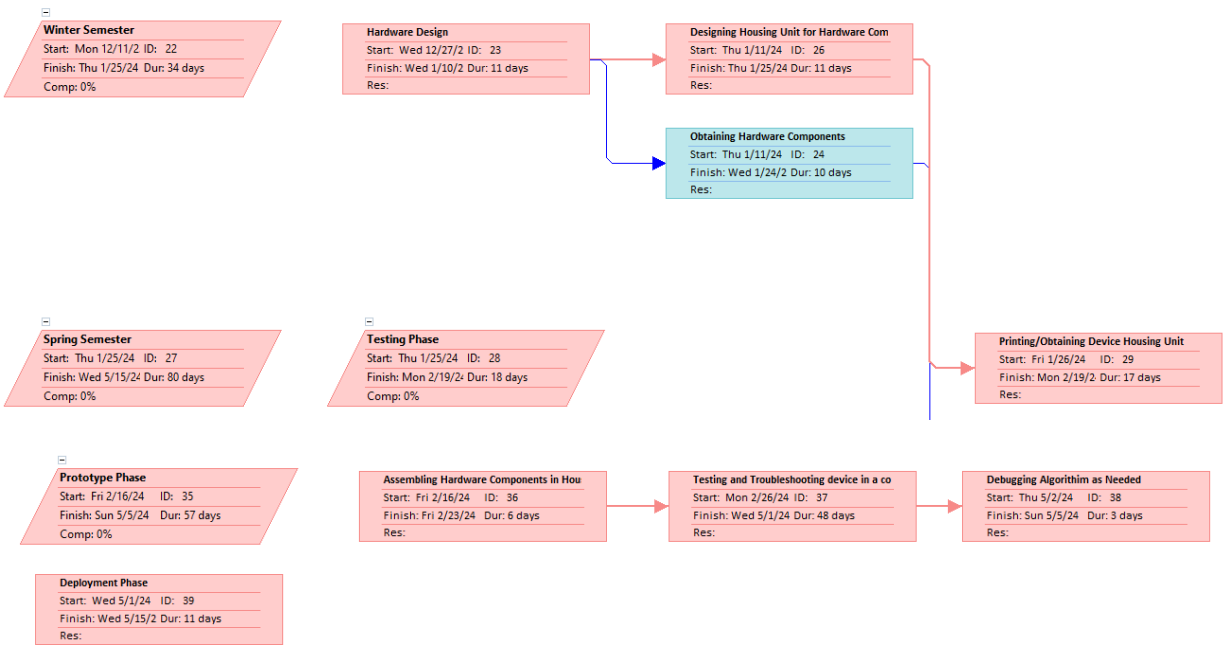
2.5 Network Diagram





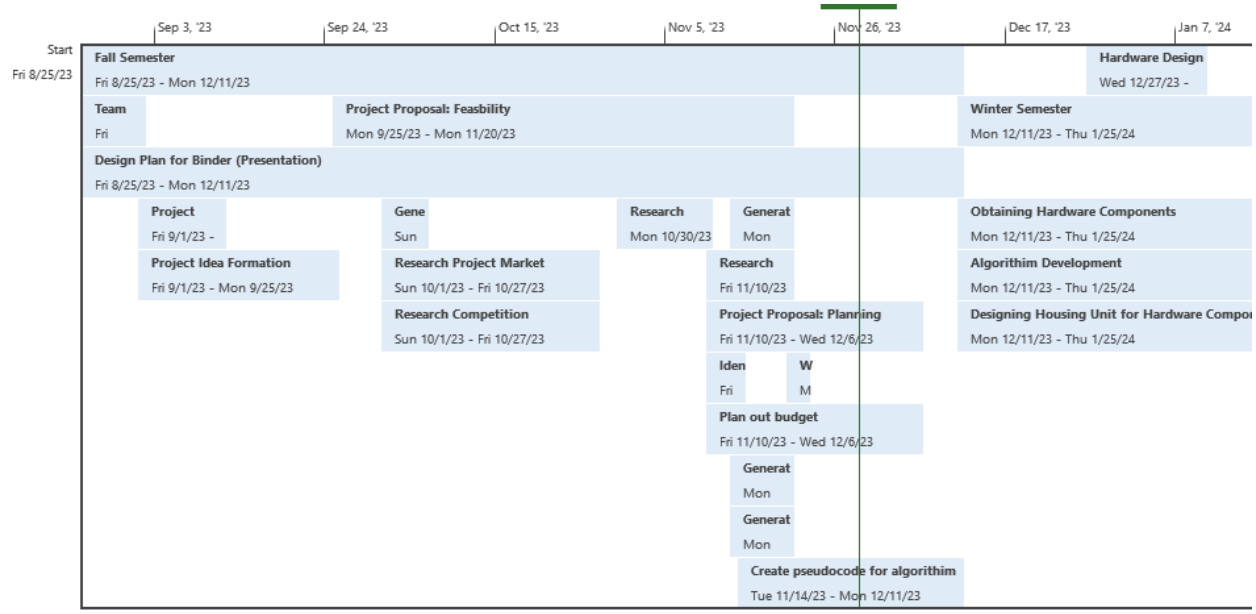
——-

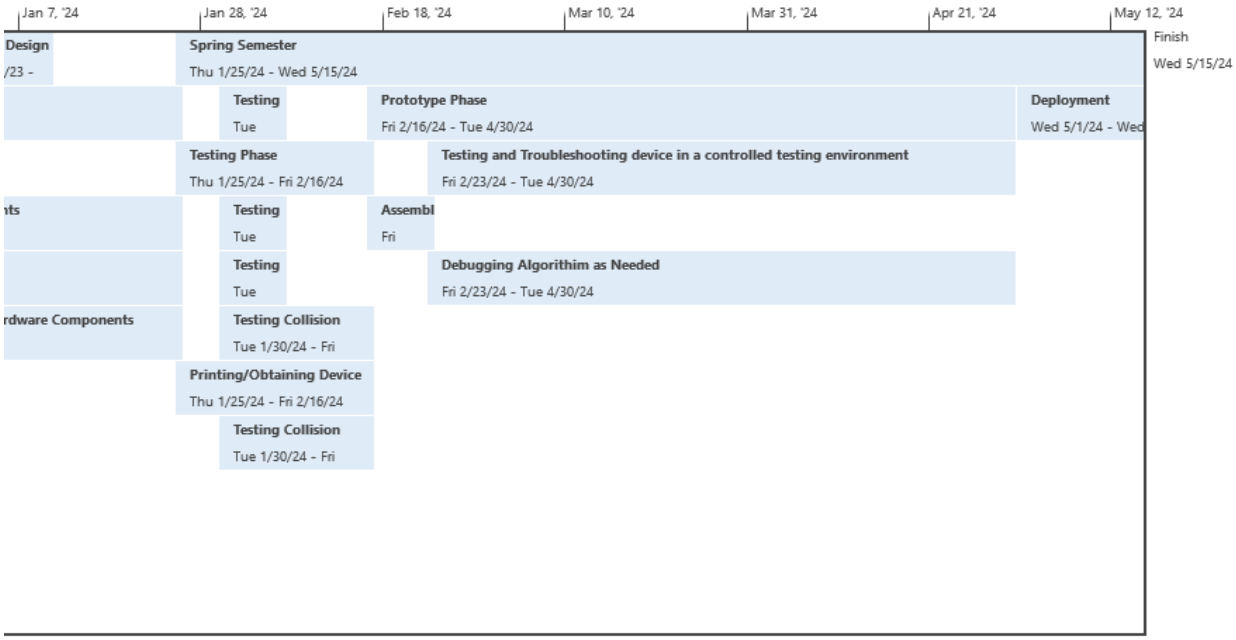
2.5.1 Critical Paths



2.6 Project Schedule: Gantt Chart

1			**Senior Design Project (Fall 23 - Spr 24)**	**189 days**	**Fri 8/25/23**	**Wed 5/15/24**	
2			**Fall Semester**	**77 days**	**Fri 8/25/23**	**Mon 12/11/23**	
3			Team Formation	6 days	Fri 8/25/23	Fri 9/1/23	
4			Project Advisor Interviews	7 days	Mon 9/4/23	Tue 9/12/23	3
5			Project Idea Formation	8 days	Wed 9/13/23	Fri 9/22/23	4
6			**Project Proposal: Feasbility**	**43 days**	**Mon 9/25/23**	**Wed 11/22/23**	
7			Generate Project Intro	6 days	Sun 10/1/23	Fri 10/6/23	
8			Research Project Market	21 days	Sun 10/1/23	Fri 10/27/23	
9			Research Competition	21 days	Sun 10/1/23	Fri 10/27/23	
10			Research Limitation, Regulations, Standards, Patents	10 days	Mon 10/30/23	Fri 11/10/23	
11			Research Constraints	7 days	Fri 11/10/23	Mon 11/20/23	
12			Write Project Charter	3 days	Mon 11/20/23	Wed 11/22/23	
13			**Project Proposal: Planning**	**22 days**	**Fri 11/10/23**	**Mon 12/11/23**	
14			Identify deliverables	3 days	Fri 11/10/23	Tue 11/14/23	
15			Generate Project Scope	6 days	Mon 11/13/23	Mon 11/20/23	
16			Generate Block Diagram for Project	6 days	Mon 11/13/23	Mon 11/20/23	
17			Generate Work Diagram for Project	6 days	Mon 11/13/23	Mon 11/20/23	
18			Plan out budget	12 days	Tue 11/21/23	Wed 12/6/23	15
19			Create pseudocode for algorithim	20 days	Tue 11/14/23	Mon 12/11/23	
20			**Design Plan for Binder (Presentation)**	**77 days**	**Fri 8/25/23**	**Mon 12/11/23**	
21			**Winter Semester**	**34 days**	**Mon 12/11/2**	**Thu 1/25/24**	
22			Hardware Design	11 days	Wed 12/27/23	Wed 1/10/24	
23			Obtaining Hardware Components	10 days	Thu 1/11/24	Wed 1/24/24	22
24			Algorithim Development	34 days	Tue 11/21/23	Fri 1/5/24	16
25			Designing Housing Unit for Hardware Components	11 days	Thu 1/11/24	Thu 1/25/24	22
26			**Spring Semester**	**80 days**	**Thu 1/25/24**	**Wed 5/15/24**	
27			**Testing Phase**	**18 days**	**Thu 1/25/24**	**Mon 2/19/24**	
28			Printing/Obtaining Device Housing Unit	17 days	Fri 1/26/24	Mon 2/19/24	25
29			Testing Arduino	6 days	Fri 1/26/24	Fri 2/2/24	23
31			Testing LIDAR Sensor	6 days	Fri 1/26/24	Fri 2/2/24	
32			Testing Bluetooth Module	6 days	Fri 1/26/24	Fri 2/2/24	
33			Testing LED	6 days	Fri 1/26/24	Fri 2/2/24	
34			Testing Collision Blind Spot Algorithim with LIDAR Sensor Data	14 days	Mon 1/8/24	Thu 1/25/24	
35			Testing Collision Prevention Algorithim with LIDAR Sensor Data	14 days	Mon 1/8/24	Thu 1/25/24	
36			**Prototype Phase**	**57 days**	**Fri 2/16/24**	**Sun 5/5/24**	
37			Assembling Hardware Components in Housing Unit	6 days	Fri 2/16/24	Fri 2/23/24	
38			Testing and Troubleshooting device in a controlled testing environment	48 days	Mon 2/26/24	Wed 5/1/24	
39			Debugging Algorithim as Needed	3 days	Thu 5/2/24	Sun 5/5/24	
40			**Deployment Phase**	11 days	Wed 5/1/24	Wed 5/15/24	


Sep 3, '23
Sep 24, '23
Oct 15, '23
Nov 5, '23
Nov 26, '23
Dec 17, '23
Jan 7, '24
Start
Fri 8/25/23
Fall Semester
Fri 8/25/23 - Mon 12/11/23
Hardware Design
Wed 12/27/23 -
Team
Fri
Project Proposal: Feasbility
Mon 9/25/23 - Mon 11/20/23
Winter Semester
Mon 12/11/23 - Thu 1/25/24
Design Plan for Binder (Presentation)
Fri 8/25/23 - Mon 12/11/23
Project
Fri 9/1/23 -
Gene
Sun
Research
Mon 10/30/23
Generat
Mon
Obtaining Hardware Components
Mon 12/11/23 - Thu 1/25/24
Project Idea Formation
Fri 9/1/23 - Mon 9/25/23
Research Project Market
Sun 10/1/23 - Fri 10/27/23
Research
Fri 11/10/23
Algorithim Development
Mon 12/11/23 - Thu 1/25/24
Research Competition
Sun 10/1/23 - Fri 10/27/23
Project Proposal: Planning
Fri 11/10/23 - Wed 12/6/23
Designing Housing Unit for Hardware Compo
Mon 12/11/23 - Thu 1/25/24
Iden
Fri
W
M
Plan out budget
Fri 11/10/23 - Wed 12/6/23
Generat
Mon
Generat
Mon
Create pseudocode for algorithim
Tue 11/14/23 - Mon 12/11/23


Jan 7, '24
Jan 28, '24
Feb 18, '24
Mar 10, '24
Mar 31, '24
Apr 21, '24
May 12, '24
Finish
Wed 5/15/24
Design
/23 -
Spring Semester
Thu 1/25/24 - Wed 5/15/24
Testing
Tue
Prototype Phase
Fri 2/16/24 - Tue 4/30/24
Deployment
Wed 5/1/24 - Wed
Testing Phase
Thu 1/25/24 - Fri 2/16/24
Testing and Troubleshooting device in a controlled testing environment
Fri 2/23/24 - Tue 4/30/24
nts
Testing
Tue
Assembl
Fri
Testing
Tue
Debugging Algorithim as Needed
Fri 2/23/24 - Tue 4/30/24
rdware Components
Testing Collision
Tue 1/30/24 - Fri
Printing/Obtaining Device
Thu 1/25/24 - Fri 2/16/24
Testing Collision
Tue 1/30/24 - Fri

2.7 Budget

Fall Semester (Research)	$0
Winter Semester ($150)	Hardware Components
Spring Semester ($100)	Allocated Budget for Issues that Might Arise

2.7.1 Cost

Item	Price
LIDAR Sensor (2)	$49.80
Microcontroller	$24.00
Bluetooth Module	$11.00
Battery for Testing	$15.00
Total	$100.00 (+tax,shipping, and handling)

Chapter 3
Organization

3.1 List of Components

Table of Components

Index	Item	Model No.	Quantity	Possession	Source	Remarks
1	LIDAR Sensor	TF Luna LIDAR Module (713-101990656)	2	Needs to Purchase	Online Purchase	
2	Microcontroller	Arduino UNO REV 3 (713-102990189)	1	Needs to Purchase	Online Purchase	
3	Bluetooth Module	HC-05 6 Pin Wireless Bluetooth RF Transceiver Module Serial BT Module	1	Needs to Purchase	Online Purchase	
4	Power Supply	12 V Power Supply (BW HR 12-30W FR)	1	Needs to Purchase	Online Purchase	
5	Housing Unit		1	Needs Design in Solidworks	Use Grove School 3D Printing Facilities	
6	Resistors		TBD	In Possession	Personal EE Lab Kits	
7	LED		2	In Possession	Personal EE Lab Kits	
8	Bluetooth Headset	JZAQ Motorcycle Helmet Bluetooth Headset	1	In Possession	Donated by team member	

We will also be using the lab rooms in the Grove School of Engineering to build and test our product. We will be using the lab equipment such as voltage sources, voltmeters and oscilloscopes to refine the workings of our product and find any errors in the design of our project.

3.2 Vendors

1. LIDAR Sensor:

Company Name	Mouser Electronics
Address	1000 North Main Street, Mansfield, TX 76063 USA
Phone	(800) 333-9924
Link	https://www.mouser.com/ProductDetail/Seeed-Studio/101990656?qs=vmHwEFxEFR%2FGuLjB%252BDw9Gg%3D%3D
Possession	Needs To Be Purchased
Price	$24.90

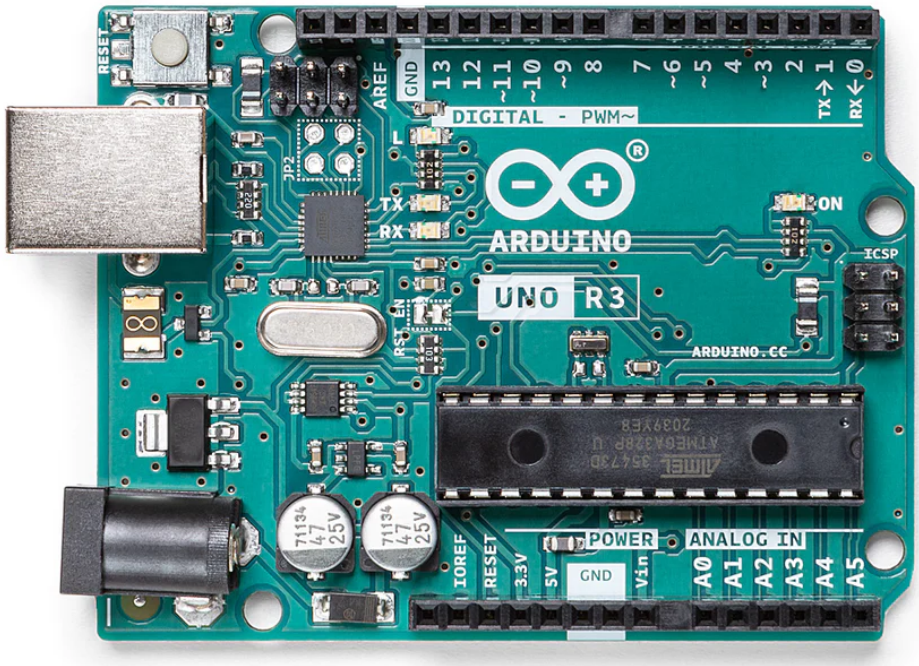
Company Name	Electro Maker
Address	North St, Poole BH15 1NX, UK
Phone	+44 1202 237137
Link	https://www.electromaker.io/shop/product/tf-luna-lidar-module-short-range-dist

	ance-sensor?gad_source=4&gclid=Cj0KCQiA35urBhDCARIsAOU7QwkgFtuFiJbyKu-foZFPeC63I7hXlDSFc7fhmWpbYXOI2242-nxcH6YaAmE9EALw_wcB
Possession	https://www.electromaker.io/shop/product/tf-luna-lidar-module-short-range-distance-sensor?gad_source=4&gclid=Cj0KCQiA35urBhDCARIsAOU7QwkgFtuFiJbyKu-foZFPeC63I7hXlDSFc7fhmWpbYXOI2242-nxcH6YaAmE9EALw_wcB
Price	$24.90

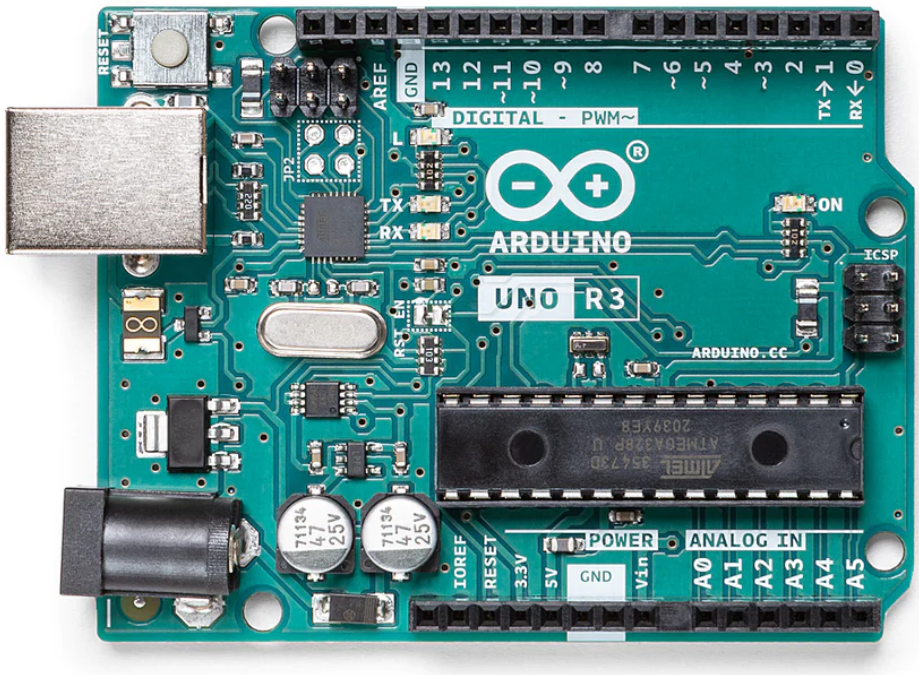
Company Name	OZ Robotics
Address	Oz Robotics 240 W 40th Street, 3rd Floor New York, NY 10018 United States of America
Email	sales@ozrobotics.com support@ozrobotics.com partners@ozrobotics.com
Link	https://www.robotshop.com/products/benewake-tf-luna-8m-lidar-distance-sensor?gad_source=4&gclid=Cj0KCQiA35urBhDCARIsAOU7Qwmyb0OkMloi09NeNs6cNfoTWkGPyrrY_HPtw5KP1YS3pBQ9TAkZVMQaAkgtEALw_wcB
Possession	Needs To Be Purchased
Price	$19.98

2. Microcontroller

Company Name	Arduino Uno Open Source Platform
Address	Online (https://www.arduino.cc/)
Phone	N/A
Link	https://store-usa.arduino.cc/products/arduino-uno-rev3/?selectedStore=us
Possession	Needs To Be Purchased
Price	$23.46



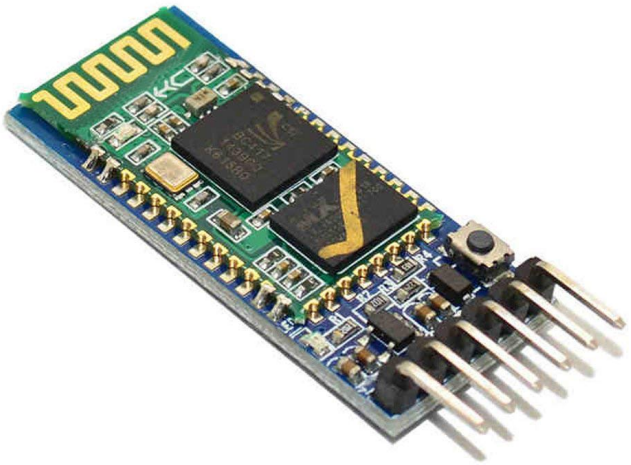
Company Name	Electro Maker
Address	North St, Poole BH15 1NX, UK
Phone	+44 1202 237137
Link	https://www.electromaker.io/shop/product/arduino-uno-rev3?gad_source=4&gclid=Cj0KCQiA35urBhDCARIsAOU7QwnRI_5ghq0qEILCgn78T1PxeoCglqJwKIlwovP2U41XJnBUxlpp5n8aAublEALw_wcB

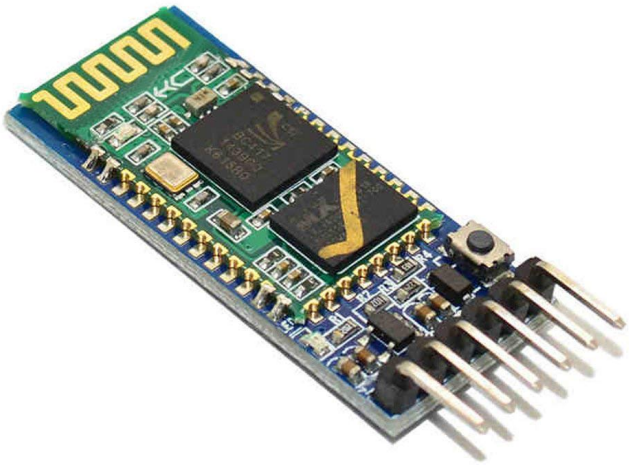
Possession	Needs To Be Purchased
Price	$28.68
	

Company Name	DigiKey
Address	701 Brooks Avenue South, Thief River Falls, Minnesota, USA
Phone	1 (800) 858-3616
Link	https://www.digikey.com/en/products/detail/arduino/A000066/2784006?utm_adgroup=&utm_source=google&utm_medium=cpc&utm_campaign=PMax%20Shopping_Product_Low%20ROAS%20Categories&utm_term=&utm_content=&utm_id=go_cmp-20243063506_adg-_ad-__dev-c_ext-_prd-2784006_sig-Cj0KCQiA35urBhDCARIsAOU7QwkLGzdrmlZpVkcn65IhLwBxrHfT3yVF3huZKHOqFTBHNGlY5RdCOHMaAinyEALw_wcB&gad_source=4&gclid=Cj0KCQiA35urBhDCARIsAOU7QwkLGzdrmlZpVkcn65IhLwBxrHfT3yVF3huZKHOqFTBHNGlY5RdCOHMaAinyEALw_wcB
Possession	Needs To Be Purchased
Price	$27.60

3. Bluetooth Module

Company Name	HiLetgo
Address	Room 1323-1327, Huanqiu Wuliu Zhongxin, HuaNanCheng, PingHu, LongGang, Shenzhen, Guangdong, China. 518111
Phone	+86-0755-36625387
WeChat	L13066806553
Email	sales@hiletgo.com
Link	http://www.hiletgo.com/ProductDetail/2152062.html https://www.amazon.com/HiLetgo-Wireless-Bluetooth-Transceiver-Arduino/dp/B071YJG8DR
Possession	Needs To Be Purchased
Price	$10.39



Company Name	Aliexpress
Address	Online
Link	https://www.aliexpress.com/i/2251832786426738.html?gatewayAdapt=4itemAdapt
Possession	Needs To Be Purchased
Price	$3.98
	

Company Name	Bonanza
Address	Online
Link	https://www.bonanza.com/listings/HiLetgo-HC-05-Wireless-Bluetooth-RF-Transceiver-Master-Slave-Integrated-Bluetoot/1535885720?goog_pla=1&gpid=&keyword=&goog_pla=1&pos=&ad_type=pla&gad_source=4&gclid=Cj0KCQiA35urBhDCARIsAOU7QwkJTMi89u4Dl7mBJaDFErMwljWHwu3JKj2A3qeV24obII-F0eG0iVAaAnMVEALw_wcB
Possession	Needs To Be Purchased

Price	$20.99

4. Power Supply

Company Name	DigiKey
Address	701 Brooks Avenue South, Thief River Falls, Minnesota, USA
Link	https://www.digikey.com/en/products/detail/continental-battery-systems/BW%2520HR%252012-30W%2520FR/12808543?utm_adgroup=&utm_source=google&utm_medium=cpc&utm_campaign=PMax%20Shopping_Product_Low%20ROAS%20Categories&utm_term=&utm_content=&utm_id=go_cmp-20243063506_adg-_ad-__dev-c_ext-_prd-12808543_sig-Cj0KCQiA35urBhDCARIsAOU7Qwnak_guTts8VXC2aumaIGlSu6RUmAS6GsXZZQlbGlk-olnV1nmV2UcaAieUEALw_wcB&gad_source=1&gclid=Cj0KCQiA35urBhDCARIsAOU7Qwnak_guTts8VXC2aumaIGlSu6RUmAS6GsXZZQlbGlk-olnV1nmV2UcaAieUEALw_wcB
Possession	Needs To Be Purchased
Price	$12.93

Company Name	Mighty Max Battery
Address	Mighty Max Battery 3775 Park Avenue Unit 3 Edison, NJ 08820
Phone	Online
Link	https://www.mightymaxbattery.com/shop/12v-sla-batteries/ml9-12-12-volt-9-ah-sla-battery/
Possession	Needs To Be Purchased
Price	$24.99

Company Name	The Home Depot
Address	2455 Paces Ferry Road Northwest, Atlanta, GA 30339
Phone	1 (800) 430-3376

Link	https://www.homedepot.com/p/MIGHTY-MAX-BATTERY-12-Volt-7-Ah-Sealed-Lead-Acid-SLA-Rechargeable-Battery-ML7-12/307979135
Possession	Needs To Be Purchased
Price	$19.99

Company Name	Amazon
Address	410 Terry Ave N, Seattle 98109, WA
Phone	1 (888) 280-4331
Link	https://www.amazon.com/gp/product/B07XSMT1MJ/ref=ppx_yo_dt_b_search_asin_title?ie=UTF8&th=1
Possession	Already purchased
Price	N/A

3.3 List of Human Resources

Prof. Ping-Pei Ho - Project Advisor/Sponsor

Prof. Edward Baurin - Project Management Advisor

David Wang - Project Manager - Algorithm Development

Iftiak Ahmed - Project Member - Designer.

Kevin Campoverde - Project Member - Prototype Tester

Li Ting Melisa Chen Chen - Project Member - Algorithm Development, Prototype Tester

3.4 Datasheets

Arduino Uno
https://docs.arduino.cc/resources/datasheets/A000066-datasheet.pdf

TF Luna LIDAR Sensor
https://www.mybotshop.de/Datasheet/Benewake_TF-Luna_Datasheet.pdf

APPENDIX A: Patents

APPENDIX B: Datasheets