

Making Rural Roads Safer with ELSA  
(Electroluminescent Safety Apparatus)

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A blue and white sign

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# Executive Summary

This report discusses the project ‘Making Rural Roads Safer with ELSA’ in large detail. It includes the motivation behind the project and the problems given to the team, an overview of the sponsor, our technical approach, our design, and a fully complete business plan. The project consists of the creation of an EL (Electroluminescent) sign breadboard prototype, which is to be called Electroluminescent Safety Apparatus, or ELSA for short. We worked closely with Richard Davids in order to come up with a design configuration, and also a conceptual software framework that ELSA might be able to be a primary function in.

Research on EL technology was important as the design depended on how the electrical flow works on Electroluminescence. Lumilor was suggested by our sponsor as the EL panel candidate.

This project is a 3-phase project and this report concludes the end of phase 1. Future phases are dependent on increased interest and the budget, possibly from more sponsors or through a grant to the CTDOT.

# Project Introduction

In 2019, the fatality rate on rural roads was nearly twice as high as on urban ones, according to the Insurance Institute for Highway Safety. In 2019, over 16,000 people died in a crash on a U.S. rural road even though only about a fifth of the population lives in rural areas according to the National Highway Traffic Safety Administration. Nine out of 10 rural traffic fatalities occur on two-lane roads, according to a May 2020 report by TRIP, a national nonprofit transportation research center. In 2015, Connecticut had the deadliest rural roads in the United States.

Transportation experts say a combination of higher speeds, narrow shoulders, lack of lighting, and lots of curves contribute to the problem. There is plenty of signage to attempt to mitigate these problems. The Manual on Uniform Traffic Control Devices (MUTCD) manual identifies over 500 warning and caution signs, object markers for conventional roads, highways, toll booths, intersections, pictographs, and worded signs; there is no paucity of signage. Each sign has exact specifications as to orientation, location, placement, etc.

The 2021 federal government infrastructure bill pledges between $300 and $750 million to make rural roads safer. In the US House of Representatives, lawmakers filed a bill in April 2021 that would create a $600 million competitive grant program that local governments could apply for to make infrastructure safety improvements on rural roads.

Why, then, is the federal government investing so much money? Something very subtle and more pervasive is happening on rural roads, not highways. It involves how humans perceive depth. While accident data is important (driver age, crash trees, etc.), this study investigates the more subtle, less obvious but extremely important precursors to an accident. This project seeks to identify what is missing on rural roadways that could prevent roadway departures and accidents by reducing speed.

This project is going to focus specifically on single-vehicle roadway departures and their causes. Some experts attribute high accident rates on rural roads to factors such as narrow turns, inadequate lighting, and windy roads. There are other factors to consider though, such as how well drivers are paying attention to the road, whether the correct signs are in the correct places, and how weather conditions can affect the safety of a given road. However, a potential factor that could explain increased single-vehicle roadway departures is how humans perceive depth.

We believe that creating a sensor based EL sign can catch the attention of drivers and make them slow down, preventing rural road accidents from happening due to not having enough time to react to a sharp turn.

#### Technical Review

# Problem Definition

## Stake Holders

ELSA is only a concept test and has an impact on Richard Davids, the CTDOT, and the CTSRC. If our prototype model works well without failures and can produce results in catching the attention of people through the EL panel sign, then this project will be deemed a success. This idea will then be presented to the CTDOT with a grant proposal that will be awarded to the CTSRC in order to have ELSA implemented into their driving simulator lab. Future stakeholders may include the companies and government agencies that are involved in road safety.

## Scope

Richard Davids approached us with the objective of slowing down the speed of drivers on rural roads. Our scope is to create a sign using our knowledge of electrical circuitry and human engineering on rural roads, and to create a conceptual framework that ELSA will operate in. The completion of these is the success of phase 1. The next step would be to move this project forward from a prototype to a full-size functional model that can be placed and tested to see if results are created. The long-term goal of this project is to have ELSAs in many high-priority rural road areas, and also have the technology be used widely across the globe.

## Service Environment

ELSA will be implemented on high-priority rural roads, those being rural roads that have high accident rates due to bad depth perception, poor road sign placements, poor lighting, etc. However, before it can be implemented on real roads, it must be implemented and tested in the CTSRC driving simulator, which is simulated in Unreal Engine, a program that simulates physics engines.

## Previous Work

Richard Davids had done some research on EL technology and Lumilor prior to approaching us with the project. In Figure 1 you can see Lumilor’s electroluminescent coating in layers that help us visualize how it works.

Table

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*Figure 1. Layers on an EL coating by Lumilor*

## Deliverable Requirements

Through meetings with Richard Davids, our team was able to identify a few key variables that would lead to the success of this project.

1. Research EL technology and Road statistics
2. Develop a breadboard to connect sensors and power to an Electroluminescent panel(s)
3. Develop a conceptual ELSA framework.
4. Reach out to CTSRC for discussion of project future.

# Design Description

Our design process is simple as it uses the main Arduino board that connects the sensors, the power input, as well as the EL panels in order to have the system running on a small scale. The color on the EL panels was important, but the brightness of them will matter just as much as the color, so the decision was to have one Aqua and one Green, the brightest colors, and to have one standard yellow panel which is the weakest in the brightness of all of Lumilor’s EL panels. A sound sensor is included to detect the sound of a car passing in order to activate the main panel, which says to slow down. A secondary humidity and temperature sensor are included in order to power a second auxiliary sign which would say “ICY” during weather conditions that may prove the road to have ice. The design also includes a GPS shield, a GPS antenna, and a Wi-Fi shield in order to, in the future, connect to a smartphone interface and give live data over the internet.

|  |
| --- |
| **Design Process Flow Diagram** |
|  |

Table 1: Design Process Flow Diagram

# Design Evaluation

In terms of requirements and specifications, our EL road sign will consist of three vertically cascaded 8”x10” panels. Two of these panels will operate on either a temperature/humidity sensor or a sound sensor, and one of the panels will be a standard sign that will operate when the sensors are not tripped. The signs cannot be on all the time, which is a specification that we must account for when making the signs.

The signs will also be powered by a 12V battery, and this battery will be charged by a solar panel (we are speculating 50W). For this, we will utilize a 12V PWM (pulse width modulation) charge controller, as this is cost effective, ideal for smaller systems, and has a longer lifespan than MPPT (maximum power point tracking) charge controllers due to having less components. Our design will also include a Seeeduino MEGA microcontroller with an ethernet and GPS shield (for internet and ArcGIS connectivity). DC/AC inverters will also be necessary for each individual panel since electroluminescence requires AC voltage.

The W5500 ethernet shield has an operating voltage of 3.3V, and the GPS shield has an RX (receiver) current of 10.3mA. The GPS shield has a power acquisition current of 25mA and a power-seeking current of 20mA. The temperature/humidity sensor being used will operate at a current of 1.3-2.1mA (input voltage 5V/3.3V), with an operating temperature of -20 to +60 degrees Celsius (or -4 to 140 degrees Fahrenheit) and an accuracy of +/-5%.

The sound sensor will operate at a current of 4-5mA, with a voltage range of 4-12V. Given that all of our components draw a considerably low amount of current, we estimate that a 100 Ah (Amp-hour) 12V battery would be sufficient for the power demands of our design.

It was important for us to consider the sensitivity of the sound sensor, as Richard has specified that the sign shall not be on all the time, and we only want the sign to activate when the sound sensor detects a car passing by. Using a sound sensor that is too sensitive would result in subtle noises (such as pedestrians walking by while having a conversation) so a low microphone sensitivity would be optimal for this system. The sound sensor has a sensitivity of -60dBV to -56dBV, which would only pick up loud noises such as a car (or other motor vehicles) passing by.

The sponsor has also requested that we figure out a way to use the duration of sounds picked up by the sensor to estimate the speed of each vehicle passing by and store this information for DOT and CTSRC analysis. Through Figure 2 below, discovered that the sensitivity of our sound sensor is low on the dBV side, which is optimal for our system.

Chart

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*Figure 2. Microphone Sensitivity Diagram*

The list of standards that pertain to this project is rather short. The sponsor has specified that he would like the system to be grounded. For this, we shall refer to NEC (national electrical code) article 250.66 in Table 2, which pertains to the grounding and bonding of electrical systems.

Table

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*Table 2:NEC Article 250.66, Grounding Electrode Size Chart*

While no final decisions have been made on the grounding of the system, we speculate that we will be able to use a ground rod as a connection for a grounding electrode conductor and attach the two components of our grounding system using an acorn clamp. NEC code article 250.66 requires that a singular grounding rod must have an earth resistance of no more than 25 ohms. When it comes to testing the grounding system, IEEE standard 81, which includes the “Three Point Fall-of-Potential” shall be used. This testing method is effective for small systems with an earth resistance greater than one ohm.

Bonding is also another important consideration, which involves ensuring that all metallic components in a system maintain electrical continuity. This means that all components must have the same potential relative to the earth's resistance (in our case a grounding rod). Grounding and bonding are not only important for preventing damage to components of the system, but also for protecting personnel from the risk of electric shock. Figure 3 below reveals our plan for grounding.

Diagram, schematic

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*Figure 3. Grounding Rod Diagram*

Since our system will use a 12V lithium-iron phosphate or lead-acid battery, we have to consider the EPA and DOT regulations in regard to disposal once the battery has reached the end of its life. For disposal of these batteries, we will refer to the DOT Hazardous Materials Regulations standards (HMR; 49 CFR parts 171-180).

In regard to alternate designs/solutions, we initially intended on using a motion sensor to detect an oncoming vehicle and activate the respective sign panel(s). However, there was some controversy that involved the detection range of the compatible sensor. The sensor the team originally intended to use from Seeedstudio only had a detection range of approximately 18 ft. This was not satisfactory for our project, as a speeding car could clear multiple times that distance in a matter of a few seconds, leaving the driver little to no time to notice the message displayed by the sign system.

Due to this, the sponsor specified that a detection range of 200 ft was required. This was a reasonable request, as it would allow a speeding driver to see the displayed message on the sign for a few seconds before passing. We eventually found a sensor that satisfied the desired detection range, but it was almost 10 times more expensive than the original motion sensor, and we were not completely sure that it would be compatible with our Seeeduino MEGA microcontroller (as this sensor was intended for use in security systems).

Ultimately, the team and the sponsor decided to shift to using a sound sensor for the purpose of detecting an oncoming vehicle, ensuring compatibility with the microcontroller being used.

Originally, this project was meant to include the Civil and Environmental Engineering department, and there was going to be utilization of ArcGIS, as well as outsourcing of development of CTSRC simulation software using the Unreal Engine. However, due to a lack of support from the CEE department, these aspects of the project were ultimately cut from the scope.

A nonfunctional smartphone interface was also included in the scope of this project. However, the sponsor has indicated that this is non-essential, and the main priority should be configuring a breadboard prototype and achieving sign functionality based on readings received from respective sensors.

As far as hardware implementation goes for this project, the main priority was getting optimal voltage to the EL sign panels, which is 12V-18V DC. This could be done in multiple ways, and the most ideal way was to develop a switching circuit. A switching circuit would involve components such as an NPN bipolar junction transistor, flywheel diode, and a relay.

The main idea behind this design would be that when a sensor detects that certain environmental conditions have been met, it sends a 5V DC signal (which can be thought of as a logical high in this case) as an input to the switching circuit. This 5V output from the microcontroller would then result in the operation of the relay into the ON position, thus powering the sign.

Diagram

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*Figure 4. Switching Circuit Diagram*

Another option for achieving optimal voltage involves the use of non-inverting operational amplifiers. In this case, two resistors are used, with Rin and Rf being connected to negative and output ports, with Rin being grounded. Vin (5V) is then applied to the positive port of the operational amplifier, and gain is determined by the equation shown below. With Rin being 1kΩ and Rf being 1.75kΩ, the voltage gain is 2.75, meaning that 5V is amplified to 13.75V at the output.

When doing this, it is important to ensure that the digital pins of the microcontroller are not experiencing a current of over 40mA, as this can cause permanent damage to the internal transistors.

*Diagram, schematic

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*Figure 5. Operational Amplifier used for achieving Optimal Voltage.*

*With Vin = 5V, Rin = 1kΩ and Rf = 1.75kΩ, Gain = 2.75 and Vout = 13.75V.*

Although a switching circuit is the most optimal option for this design, time constraints unfortunately prevented the acquisition of necessary relays. This meant that the team had to ultimately use operational amplifiers for this design. For future teams that work on this project, the ECE team strongly recommends using a switching circuit and getting parts for this far in advance.

In terms of programming (which was done in Arduino IDE), the idea is rather simple. The code is set up such that every five seconds, a reading is taken from a given sensor. The readings from a given sensor are then populated into an array, and each entry in the array is used in a conditional statement regarding environmental readings such as temperature/humidity and sound levels. In the block of code located within each conditional, if the condition is met, then the associated output pin is set to HIGH (5V), otherwise the associated output pin is set to LOW(0V).

# Design Recommendations

## Currently Recommended Design

Based on our design evaluation, our recommendation to Richard Davids is to have a main Arduino interface that connects the power, sensors, and EL panels together on a post. We do not want to stray too far from a regular road sign, so our design will want to replicate that of modern road signs. One decision made to counter the original design is to use a sound sensor rather than a long-range motion sensor, as it would ensure compatibility with the microcontroller and is also much cheaper while also satisfying the desired detection range.

## Future Design Requirements

Our design was created with our project budget of $1000 in mind, but there are many parts that can be upgraded in the future as the cost of materials is reduced as manufacturing starts. The sound sensor can be upgraded to a motion or distance sensor in the future for better detection of oncoming vehicles.

#### Business Plan

# Company Overview

## Company Introduction

Richard C. Davids. Mr. Davids is a cancer survivor and retired senior staff human factors engineer with Lockheed Martin Missiles and Space Systems, Sunnyvale, California, 1974 – 2007. He applied human factors engineering principles and design standards to mobile command shelters, large communication facilities, missiles, ships, planes, spacecraft, the Office of the Secretary of Defense Crisis Coordination Center, the ISS, transportation systems, railcars, missile and submarine support equipment, electronic equipment, and computer-human interfaces. Since 2011, he has sponsored and privately funded 13 Engineering Capstone, Honors, and Senior Design projects at the University of Rhode Island, the University of Connecticut, and Roger Williams University. His projects won regional and international awards. He lives in a rural area, and often notices tire tracks that can be traced to the embankment off-road. His objective for the project was to reduce drivers’ speeds on rural roads in order to prevent more accidents from happening.

## Technology

There is a wide variety of technology that will be used for this project. The most important use of technology in this project is electroluminescent paint, which is 5 separate layers of paint with different additives dispersed within. Electroluminescent paint will be painted on the panels and lit through the installed sensors in the hope that it will reduce the speed of oncoming vehicles. Additionally, we will also be using sound, temperature, and humidity sensors in order to gather data on all 3 variables and display an appropriate message on the traffic sign. The breadboard configuration will be connected to the 3 sensors, and we will be using the doppler effect with the sound sensor to detect if the car is going fast or slow.

## Product/Service

The product we are offering is a traffic sign that has electroluminescent paint on the panels that will give a message to the drivers depending on the weather conditions and their speed. The hope is that drivers will see the message on the sign and adjust accordingly. Another service we are providing is a framework where data is sent from ELSA to a central hub for DOT monitoring purposes.

## Intellectual Property Status

A patent that expired in 2020 exists for illuminated traffic signs (US6422714B1), but the approach for detection in this patented sign included the sensor response to a headlight of an approaching vehicle which differs from our sound sensor design. ELSA can be patented and a provisional patent application costs between $9,000 to $16,000,1 but our sponsor does not have the financial resources to apply for a patent.

## Commercialization Strategy

Our commercialization strategy for an ELSA would involve identifying potential customers for the product, such as road construction companies or government agencies responsible for maintaining rural roads and developing a plan to market the road sign to these customers in order to generate sales. This could involve creating marketing materials, such as brochures or product demonstrations, and working with distributors or sales agents to reach potential customers. The goal of the commercialization strategy would be to make the road sign a widely recognized and trusted product within the road construction industry.

# Industry Overview

## Industry Definition and Description

The road safety industry encompasses businesses and organizations that work to promote safe driving and prevent accidents on the road. This may include companies that design and manufacture safety equipment for vehicles, as well as companies that create road safety signs. It may also include organizations that provide driver training, such as driving schools and safety courses. Additionally, the road safety industry may include advocacy groups and non-profit organizations that raise awareness about road safety issues and lobby for changes to laws and policies.

Overall, the road safety industry is focused on promoting safe and responsible driving behaviors and reducing the number of accidents and fatalities on the road. The specific industry our final product will be in is sign manufacturing, which is NAICS code 339950. Sign manufacturing is primarily engaged in manufacturing signs and related displays of all materials.

## Regulations and Policies Driving the Industry

There are many regulations and policies that govern the road safety industry. These include rules and standards related to the design and manufacture of safety equipment for vehicles, as well as the training and certification of drivers. Additionally, there are laws and policies that dictate safe driving behaviors, such as speed limits, seatbelt laws, and restrictions on distracted driving. Governments also establish policies and programs to promote road safety, such as public education campaigns, enforcement of traffic laws, and funding for safety improvements. These regulations and policies are typically established by government agencies responsible for transportation and public safety and are designed to protect the safety of drivers, passengers, and pedestrians on the road.

In terms of OSHA, EPA, CT DEEP, and other regulations, there is only one regulation that we need to follow, which is the EPA battery recycling best practicing and battery labeling guidelines.2

# Customers

## Customers & End-user

Potential customers include government agencies in charge of maintaining roads in rural areas, road construction companies that work on rural roads, and rural municipalities or townships. These customers would be interested in buying ELSA to further improve safety and navigation on rural roads if current road signs do not prove to be useful in slowing down drivers. Other potential customers include businesses or organizations that operate in rural areas which may be interested in buying ELSA for their own use. Further development on ELSA could have versions outside of road signs, which could be appealing in a variety of markets and increase potential customers.

## Buying Behavior

The buying behavior of customers of our products would be complex considering how each traffic sign may offer something different so the customers would be very thorough in their research and highly involved in the buying process. These customers would be highly involved because they understand the technical aspects of it and also want to make sure the sign is effective. However, in certain situations, when dealing with government agencies, the buying behavior may be habitual because government agencies often have contracts in place with large companies and if there is nothing wrong with their current situation, they won’t look for alternatives.

# Market

## Market Definition

### Primary market

The primary market we identified for our product was the Traffic Sign market because the main objective of our project is to develop a traffic sign to make rural roads safer and that falls in line with this market. Traffic signs are mass products, and the manufacturers have very little scope for product differentiation which makes the market highly competitive and price sensitive. The Traffic Sign Market is divided by type and by application. By Type consists of whether the sign is above 2 sqm, between 1-2 sqm, or below 1 sqm. Our sign is 8x11 feet so it will be between 1-2 sqm. The Application segment is composed of 3 types of signs, guide & direction signs, warning signs, and regulatory signs.3 Guide and Direction signs are used to help drivers navigate and to make it easier to find a particular destination. Warning signs are used to warn drivers of possible hazards or dangerous situations on the roads. Regulatory signs give drivers information about what they can do at a particular location, these include speed limit warnings and general warnings.3 We feel our product can fall into both the warning sign and regulatory sign category because the sign will tell drivers about a dangerous situation on the road as well as give speed limit warnings. However, the primary segment for our sign would be the regulatory sign market because our sign will give speed limit warnings as well as general warnings about the weather conditions and conditions of the road.

### Secondary markets

The secondary markets that we identified for our product are the road safety market and driver safety market. The road safety market is segmented into 3 categories which are based on component, technology, and road type. The component segment is divided into solutions and services based on what the product is offering. The services section of the markets consists of system integration, support and maintenance, and consulting and training.4 The solutions section consists of enforcement solutions, incident detection, response, etc. Enforcement solutions are categorized into red light enforcement, speed enforcement, and section enforcement. The technology segment of the market consists of surveillance, sensors, and analytics.4 As for the road type, it is segmented into cities, highways, or rural roads and as of 2021, cities hold the largest market share in this category.

## Primary Market

### Size and trends

The global traffic sign market was valued at $850 million in 2018 and is projected to reach $1.16 billion by 2025.3 The traffic sign market is growing at a rapid rate due to the surge in the number of road accidents and fatalities, which has increased the demand for advanced traffic signs such as regulatory and warning signs. The growth of the traffic sign market can be attributed to an increase in the number of vehicles, growing awareness about road safety, and increasing demand for digital signage. In emerging economies such as China and India, the increased demand for signage has contributed to the growth in those regions and an increase in car production across the Asia Pacific has led to increased growth in the traffic sign market. This market is trending towards digital signage and advanced signs such as automated or sensor-driven signs because they allow for more customization, and it is easier for drivers to see. Additionally, research has shown that digital or EL signs have a bigger impact on drivers passing by which has contributed to this trend.

### Current total and served-available markets.

Traffic signs are used everywhere and are essential in order to have a safe road environment for both drivers and pedestrians. Globally, this market has seen exponential growth in recent years and the current total available markets are North America, Latin America, Europe, the Middle East, Africa, and Asia Pacific. At the regional level, North America held a market share of 29% in 2015, which made it the largest market share. Europe had the 2nd largest market share with 26% followed by Asia with a market share of 19%3. The primary reason these markets hold so much of the total market share is because of government support and technological advancements resulting in the easier implementation of traffic signs. The served-available market for our product would be the North American market because it is where we are located so distribution would be much easier and it accounts for the largest market share in the global market.3

### Predicted annual growth rate.

The traffic sign market is projected to have a CAGR of 2.4% from 2021 to 2030.3

# Competitors

## Indirect Competitors

Indirect competitors for our product would be Kapsch TrafficCom, Jenoptik, and American Traffic Solutions. These companies are our indirect competitors because although they don’t make traffic signs, they manufacture products related to road safety that may eat into our market share. For example, American Traffic Solutions offers red-light cameras as well as speed cameras and although this doesn’t directly relate to what we offer, a company may choose to purchase a speed camera rather than a traffic sign warning people about their speed. Additionally, Jenoptik has products that can increase road safety, increase safety at hazardous intersections and reduce accidents on rural roads. This can impact on our product because our traffic sign is aimed at increasing road safety on rural roads and if a potential customer didn’t specifically want a traffic sign, he may choose to purchase Jenoptik’s product.

## Direct Competitors

The companies that are considered our direct competitors are USA Traffic Signs, Sign Solutions USA, and the Traffic Sign Corporation because they manufacture traffic signs that have the same purpose as ELSA. All of the companies listed sell traffic signs that serve the same purposes as ours and can potentially eat into our market share. USA Traffic Signs produce road signs that mention speeding limit, possible hazards, and weather conditions which are all the same situations our traffic sign will have so we can potentially lose customers on that. Sign Solutions and Traffic Sign Corporation also produce similar signs to us and customers who may not be familiar with Electroluminescent technology may choose to buy the standard signs.

## SWOT Analysis

Timeline

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*Figure 6. SWOT Table Analysis for Competitors*

# Marketing and Sales Plan

## Opportunity Statement

ELSA is a new and unique rural road safety invention that will reduce the number of crashes and fatalities through a dynamic notification of dangers to drivers.

## Current Customers

ELSA does not have a current customer base as it’s a product nowhere ready for sale.

## Potential Customers

Potential Customers for ELSA would include US Department of Transportations across the states, but more focused on states with high priority dangerous roads. The CTSRC would also be one of the potential customers as they are our target for further development of ELSA.

## Pricing

The ELSA prototype’s total cost came out to be $546.70 with all parts included. An estimate for the full ELSA sign was determined to cost around $1200 with a full size EL panel with a pole and enclosure for the circuitry. With labor costs in mind, ELSA is hoped to be priced at $2500 or above.

# Research and Development (R&D) Plan

## R&D Objectives

This project was Phase 1 of ELSA, and phases 2 and 3 include plans for ELSA to be incorporated into the CTSRC software. This driving simulation software will be the testing phase of ELSA where the effectiveness is tested in full. While this is going on, the development of the central server would have to be pursued. R&D past the next phases are currently unknown.

## Milestones and current status

ELSA has come from an idea that our sponsor created into a working prototype with a conceptual framework. The coding was developed, and an idea of the circuitry finished. The prototype worked in full and had no errors outputting the message it was created to make.

## Technical Risks

Certain technical risks discussed were the stealing and/or damaging of the signs. The signs have GPS location trackers on them and would need to be monitored for any damages that might be done to them. We would like to hope that citizens that live near these signs keep in mind the safety of the public and keep to themselves. Through testing on the EL panel useability after damages, any wear and tear that does not open up the EL conductive layer allows the sign to produce light.

## Staffing

For the next phases of the project, it relies on the assistance of another capstone project, as well as coordination from the CTSRC ArcGIS team. They are able to work with ELSA and the conceptual framework to make it into reality. There was no further budget that is available for the hiring of any other staff.

## R&D Budget

The R&D budget completely relies on the acquittance of a grant from the CTDOT or other DOTs. There is a $300 million-dollar rural road infrastructure safety grant program that the sponsor may apply to in the future in order to be granted a budget to work with.

# Manufacturing and Engineering (M&E) Plan

## Objectives

The Objective of manufacturing ELSA would be to create it at a low cost. Regular road signs are created with a very low cost of materials and labor, so ELSA is meant for more specific rural roadways. What ELSA is trying to beat out are the radar signs that highlight the speed you are travelling. The sign slows down drivers effectively, but at such a high cost, it’s a very simple device. ELSA should be created at a maximum cost of materials and labor of $1000 per part.

## Staffing

Staffing would include a small team of assemblers, an IT department for the central server, and a sales staff to promote the sign across the states. The sign itself is not very complex to assemble, so no specialty staff is needed for assembly.

## Quality Control

ELSA gets its materials from third parties, so quality control in-house would not be feasible. Parts coming in need to be checked with a degree of importance in each part. The EL panel would be of greatest importance as they would need to be of consistent brightness. The electrical materials come in second to importance, as they take longer to check for defects. Other materials such as the pole that the sign resides on will need its integrity checked for safety.

# Human Resource Plan

## Staffing Objectives

The staffing objective is to hire a small team to work on and develop ELSA further. The goal of this is to create a new rural road safety infrastructure first, and then to create a profit on the signs.

## Organizational Structure

1st Year: Primarily Research and Development for the product, as well as developing prototype. Testing, finding locations of high accident profile, find a shop.

2nd Year: Promote interest in CT, RI, and other states with rural road accidents.

3rd Year: Produce in small scale, parts will be from outside vendors. Extend out to RI and maybe NH or Vermont.

4th Year: Continue small scale sales alongside continued research and development, market research.

5th Year: Sell the design and company to vendor with capabilities to mass produce.

# Risk Management Plan

## Potential Risks

ELSA has some potential risks that we may need to consider in the future. Our current risks include delays, part failure, project discontinuation, and grant rejection. If any of these risks are not addressed, this project may be in a state of jeopardy and may need to be further invested by another party. This is a multi-phase project, which means that a failure in this first phase will not be as big of an impact as it would in a further phase. We have a risk matrix shown in figure 7 and table 3 below to visualize our current understanding of our risks as of this report.

Chart

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*Figure 7. ELSA Risk Matrix*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| # | Potential Threat | Impact | Probability | Level | Recommendation |
| 1. | It will take a while to implement ELSA into any sort of framework | 2 | 3 |  | Communicate with lots of people, try and get in close contact with CTDOT or CTSRC and request assistance. |
| 2. | The panels fail to work as they are intended, and the conceptual framework does not work due to this. | 4 | 1 |  | The panels can have each part replaced with testing. The biggest problem would be a lack of parts or delivery times and that would require planning ahead of time with vendors. |
| 3. | Phase 2 and 3 cannot be continued. There is a possibility that there will be no interest past Phase 1, and this will likely end the project’s development. | 5 | 2 |  | Keep interest high, make sure people remember the name and idea when a safety concern in rural roads is mentioned. Reach out to many universities for an outstanding capstone project. |
| 4. | A grant request is refused because the CTDOT and CTSRC do not see the appeal of ELSA for rural roads. | 2 | 1 |  | We are in phase 1 of this project, and ELSA is on its first iteration at the end of this phase. If the grant request is refused, the next phase would be developing a higher iteration of ELSA and its smartphone interface. |

*Table 3: Risk Matrix Threats and Recommendations*

# Financials

## Financial Objectives

The financial objective of this project is to receive a grant from a US DOT for the continuation of the ELSA project. This goal can be met through the continuation of development and research, and a backing of support from investors to the project.

## Plans for obtaining investors or strategic alliance

ELSA as an idea needs to be presented to investors to get them interested, as it is a new product with no backers behind it. Our team and Richard are very small, and it would be a large endeavor to promote the project to spread the word. Richard will need to work with future teams in the next phases in order to make the completion of ELSA and it’s infrastructure happen.

# Appendices

## Bill of Materials

Graphical user interface, table

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## GHSA 2016-2020 Crash Fatality Rate Report

Chart, pie chart

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## ELSA Conceptual Framework

Diagram

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# References

1. Forsgren Fisher McMalmont Demaea Tysver. Bitlaw guidance. Patent Application Cost (Bitlaw Guidance). <https://www.bitlaw.com/guidance/patent/what-does-a-patent-application-cost.html>. Accessed December 09, 2022.

2. Battery Collection Best Practices and Battery Labeling Guidelines. EPA. <https://www.epa.gov/rcra/battery-collection-best-practices-and-battery-labeling-guidelines>. Accessed December 14, 2022.

3. 360 Market Updates. Traffic signs market size, share, growth, regional trend, leading players updates, impact of covid-19 on business and future plans by forecast to 2028. WICZ. <https://www.wicz.com/story/47432070/traffic-signs-market-size-share-growth-regional-trend-leading-players-updates-impact-of-covid-19-onnbspbusinessnbspand-future-plans-by-forecast-to>

Published October 6, 2022. Accessed December 10, 2022.

4. Road Safety Market Size, Share & Analysis Report, 2021-2028. <https://www.grandviewresearch.com/industry-analysis/road-safety-market>.

Accessed December 11, 2022.

5. Auguste, M. E. (2019). (rep.). *2019 Connecticut Crash Facts Book* (pp. 1–94). CTSRC.

6. Hartford Courant. (2018, December 12). *Report: Connecticut has nation's Deadliest Rural Roads*. Hartford Courant. Retrieved January 27, 2023, from https://www.courant.com/2015/05/19/report-connecticut-has-nations-deadliest-rural-roads/

*7. America's rural roads: Beautiful and deadly*. Governors Highway Safety Association The States’ Voice on Highway Safety. (n.d.). Retrieved March 1, 2023, from https://www.ghsa.org/resources/GHSA/Rural-Road-Safety22

8. Jackson, E. (2022). (rep.). *FY 2022 ANNUAL REPORT*. Mansfield, CT: Connecticut Transportation Institute.