# SmartCross

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**Abstract – This paper aims at developing an alternative method and technology to prevent crosswalk accidents. A device was successfully created that utilizes a microcontroller and LED lights, which warns pedestrians if it's their right of way. This device can be connected with the current traffic system as well.**

***Keywords – Lighting system for crosswalk, LED light crosswalk, Arduino crosswalk.***

## I. INTRODUCTION

A report released in April 2014 by the U.S. Department of Transportation National Highway Traffic Safety Administration, reported that a total of 33,561 car accidents fatalities occurred in 2012. 4,743 were pedestrian fatalities (U.S. Department of Transportation, 2014) [1].This was a 6% increase from the numbers reported in 2011. In the report, it is stated, 70% of pedestrians involved in a fatal accident by a motorist occurred during the night time. The data complied specifically for this table, states that night time is between 6pm to 5:59am. In 2012, almost three-fourths (73%) of pedestrian fatalities occurred in an urban setting versus a rural setting. Nowadays, due to the influence of a social media such as Twitter, Facebook and Instagram, people are looking down on their phones and are not paying attention to whether they are about to step off the curb and onto the road. A few years ago, New York City started printing "LOOK" signs on the roads, can be seen in Figure 1, warning pedestrians of oncoming traffic.


**Figure 1: "LOOK" sign used in New York**

But over a short period of time, the signs were wearing off and just weren't that effective in catching the pedestrians' attention and warning them. At major intersections in the city, there are devices attached to a pole in the corner of each road which make different sounds to warn pedestrians of traffic right of way and pedestrian right of way. This device is meant primarily for blind pedestrians, however it can also be used by all, however, due to noise pollution, the sound is difficult to hear and people who have headphones on cannot hear the sounds that the device makes.

The project objective is to build a lighting system, which houses a microcontroller and at least 9 LEDs. The LED lights will be facing three different directions, one side facing oncoming traffic and the other two sides facing pedestrians. Three LED lights will be used for each direction. Since the plan is to embed this system into the road, shown in figure 2A, it needs to be built in a way that it can take the weight of a midsize car passing over it.

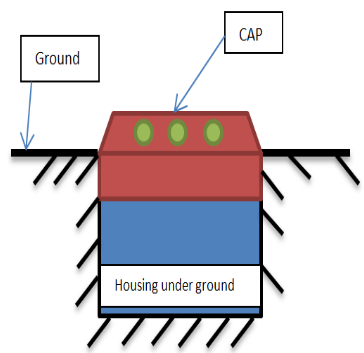



**Figure 2A: Lighting System Embedded into the Ground**

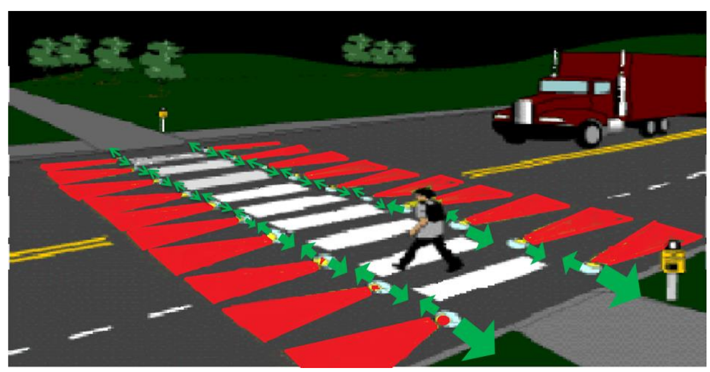


**Figure 2B: Modified Picture of Transportation and Traffic Information Center,1388 Farvadin [2]**

The objective is to create a lighting system that will be synchronized with the existing traffic lighting system. This system will either flash red lights to warn pedestrians waiting at both end of the crosswalk if it's a "Don't Walk" sign, or green lights if it's a "Walk" sign. For oncoming traffic, it will display the corresponding traffic light signal to the drivers as shown in Figure 2B.

## II. Engineering Requirements

To complete the project, some engineering requirement were set that needed to be meet. Below are the major requirements:

1) Design in a way once the housing is embedded into the ground.it gives easy access to the microcontroller and LED lights if any internal components need to be replaced.

2) Keeping the extrusion of the model from the surface of the road to a maximum of 1 inch so cars can easily drive over it and pedestrians don't trip over it.

3) Environmental Conditions

a) Material needs to be water resistant, corrosion resistant and strong enough to withstand a dynamic force of a mid-sized sedan (3000lbf) driving over it.

b) Temperature Range -10C to 85C for both the microcontroller and LED. This range is predetermined based on New York City climate conditions.

4) Lights should be visible from a distance of at least 20 ft. away.

5) Easy to synchronize to the current lighting system.

6) Maximum deformation of the cap cannot exceed 0.19685in so no damage comes to the LED lights or the microcontroller.

## III. Engineering Design

**Cap:**

The cap is 3in in diameter with 1.5in thick extrusion. The chamfer of 45 degrees is put on the top edge of the cap for cars to be able to drive over the cap easily. There are 9 LED's placed in sets of 3. 2 sets will be turned towards the pedestrians while one set is turned towards the oncoming traffic. Each section for the lights was set to be 1.5in wide with 0.5in distance from the centre of each hole where the LED lights can be seen.

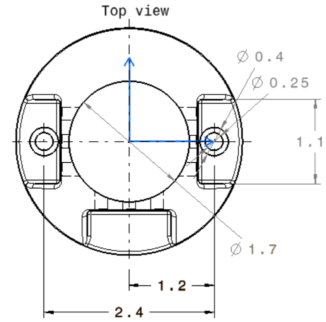



**Figure 3: Cap Dimension Top View**

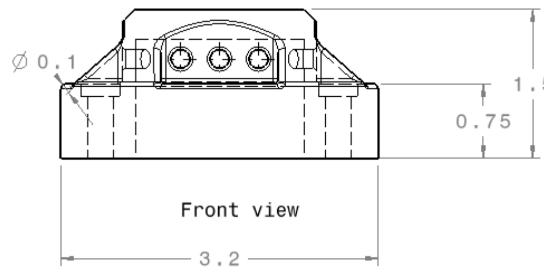



**Figure 3: Cap Dimension Front View**

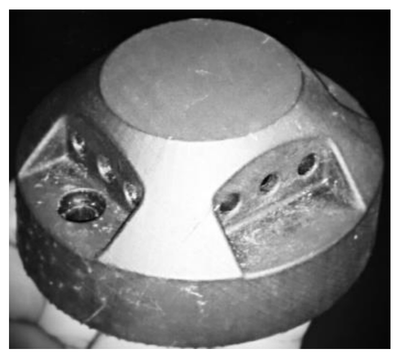


**Figure 4: Final 3D Printed Cap**

**Housing:**

The housing design is a 3in long extrusion with a 3in diameter solid cylinder with a slot cut out to house the microcontroller.

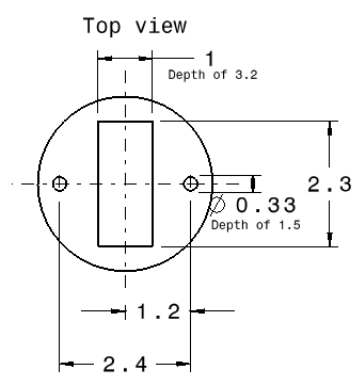



**Figure 5: Housing Dimension Top View**

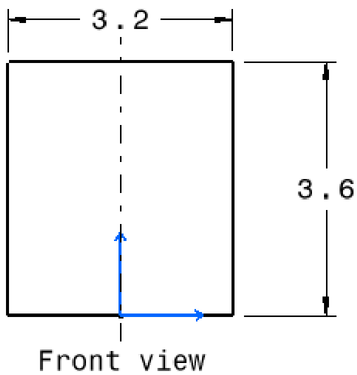



**Figure 6: Housing Dimension Front View**

**Figure 7: Final 3D Printed Housing**

To provide more support to the cap and to distribute the force that is applied on the part, it was concluded that leaving a large un-machined support area on the housing would do such that. The machined part which is a rectangle is for the microcontroller and wires.

The housing is 3.6in high by 3.2in diameter cylinder. The solid cylinder has a slot cut out for the microcontroller, shown in figure 5. The cap is a trapezoidal cylinder which is 1.5in thick and 3.2in diameter. It houses 9 LED's, 6 for the pedestrians and 3 for oncoming traffic.

1) When it came to designing, the main objective was to create a model that was simple to install and gave easy access to the microcontroller if needed. The newly designed model consists of two parts: the housing and the cap. The housing, shown in figure 6, will be fully embedded into the ground and will house the microcontroller. The cap, shown in figure 7, only 19.05 mm (0.75 inches) will be sticking out of the ground and it will display the LED lights. Two screws will connect the cap to the housing. This design provides both, easy access to the internal components and there is less extrusion of the cap from surface of the road. Refer to the end of this section for more information and refer to Appendix A for detailed sketch of the cap and the housing.

2) Like the preliminary design, the new design of the cap only sticks out 0.75 inches from the surface of the road with an chamfer angle of 45°. This allows for cars to easily drive over them without damaging the cars suspension or the lighting system.

3-a) To meet requirement three, the LED lights and microcontroller that best fitted to withstand this type of temperature range were found to be Neopixel LED lights and Arduino Uno microcontroller. For more information, see Section VIII.

3-b) The material picked was steel. Due to it having high Young's Modulus, steel was found to the better choice over the other material. Refer to Section VI.

4) NeoPixel is the latest advance in the quest for a simple, scalable and full-color LED. These LED lights give 1,000 lumens/meter, so with these LED lights there shouldn't be any problem of seeing them from 20ft away.

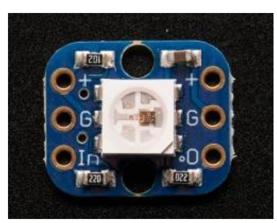
5) For this project, an Arduino Uno was picked as the microcontroller. The uno is easy to program and can easily be connected to another microcontroller. See Section VIII.

6) To ensure that the cap does not deform more than 0.19685in, finite element analysis was done. See Section VII.

## V. Component List

Arduino Uno
Dimensions: 2.95in x 2.1in x .59in
Operating Voltage: 5v
Digital Pins: 14
Analog Pins: 6

**Figure 8: Arduino Microcontroller**



RBG Smart NeoPixel
Dimensions: .4in x 0.5in x 0.098in
Protocol Speed: 800 KHz
Power required: 5-9v DC
Constant current:18.5 mA per LED

**Figure 9: Neopixel LED**

Switching Power Supply
Plug Type: 0.2in OD/
2.1mm ID 'coaxial' DC plug
Input: 110-220 AC
Output: 5v DC up to 2A

**Figure 10: Power Adapter**

method the quality of the results often strongly depends on the mesh.

## VII. Material Selection

**Table 1: Material Comparison**

| Material | Elastic Modulus | Shear Modulus | Yield Strength |
|---|---|---|---|
| | $10^6 \, lb/in^2$ | $10^6 \, lb/in^2$ | $10^3 psi$ |
| Aluminium | 10 | 3.4 | 42 |
| Gray Cast Iron | 23.5 | 0.885 | 25 |
| Steel | 29 | 12 | 51.2 |

Choosing a material suitable for the housing several factors play a significant role in the selection process. Table 1 shows various materials, their properties and compares them side by side to help choose an optimal material which needs to be strong and stiff to withstand a dynamic force of a car driving over it. Steel was chosen as the optimal material for this model, since it had the highest elastic modulus and yield strength. If the steel receives a zinc coat of paint, it will be corrosion resistant. The connection, between the cap and the housing will receive a gasket which makes the part completely waterproof. The design was tested for deformation and failure using Finite Element Analysis (FEA).

## VIII. Finite element Analysis

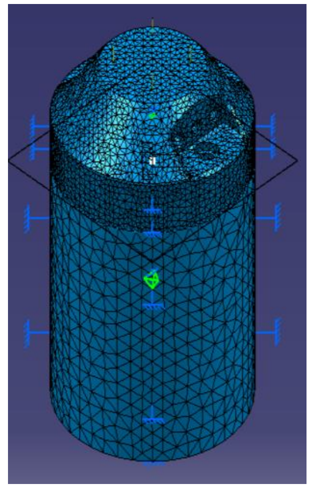
For the basic understanding of how the model will react to the force of a midsized car, FEA in a CAD program was used. This simulation with the program gave the best possible combination of material(s) with different forces. The results were obtained using the Von Misses criterion.

To start the FEA, once the parts were assembled in in CAD program, the assembly was then transferred to the FEA workbench. Below are the steps that were taken to successfully complete the FEA portion of this project:

1) Since the entire housing and part of the cap would be below the road's surface, the deflection of it is restricted. To replicate this boundary condition (BC's) in the FEA model, fixed boundary condition was added to the housing and part of the cap.

2) For the worst case scenario, the entire weight of a mid-sized car was applied using a distributed force of 3000lbf acting downwards on top of the cap.

Real-world engineering commonly involves the analysis and the design of complex models. These types of analysis depend critically on having a modeling tool with a robust geometry import capability in conjunction with advanced, easy-to-use mesh generation algorithms. For finite element



Material: Steel
Material Properties

A. Elastic Modulus = 200 GPa
B. Poisson's Ratio = 0.266
C. Yield Strength = 250 MPa

Boundary Conditions: Clamped all around to represent wall.
Loading (static): 3000lbf
Mesh type: Tetrahedral

**Figure 11: FEA result showing Boundary conditions, distributed force and mesh**

Mesh is used to analyze an entire object to be tested but it is done in sections. Tetrahedral mesh was used for the analysis. The type of mesh used was parabolic due to it being adjustable to the edges of curvature objects. Parabolic mesh allows for accurate results with minimal error. To strike a balance between accuracy and computation time, a mesh convergence study was done on the model. This is necessary in selecting as appropriate mesh size that will give acceptable results. Faster computers for high CPU power will not crash with very small mesh sizes. As the mesh size gets smaller, more computation power is required.

For the FEA test to be concluded, it is required that the results of mesh, against the results for stress, converge. At times, data recorded from the FEA experiments do not conclude a mesh convergence at which point, a best fit line is supplemental for the conclusion of the process.

There were a total of 20 different mesh sizes that were used to achieve results. From 1 inch to .05 inch for the local mesh. Increments of .05inch mesh size were used to compile accurate results. The stress results were recorded from a single point on the object every time.

In figure 14, the stress graph obtained from running 20 tests, on the FEA section of the CAD program, it is discovered that the data complied does not converge at any point nor does it linearly ascend or descend. As a last option, a "best fit" polynomial line has been placed to show a mean steady increase in the stresses as it goes from .05 inch mesh size to 1 inch mesh size.

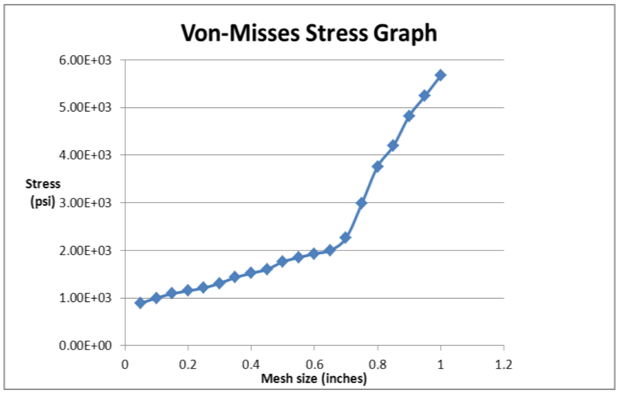



**Figure 12: Mesh Size vs Von Mises**

It can be seen from figure 14, as the mesh size is being reduced, the stress value converges. Based on the results, the acceptable mesh size for this study was chosen to be 0.05.

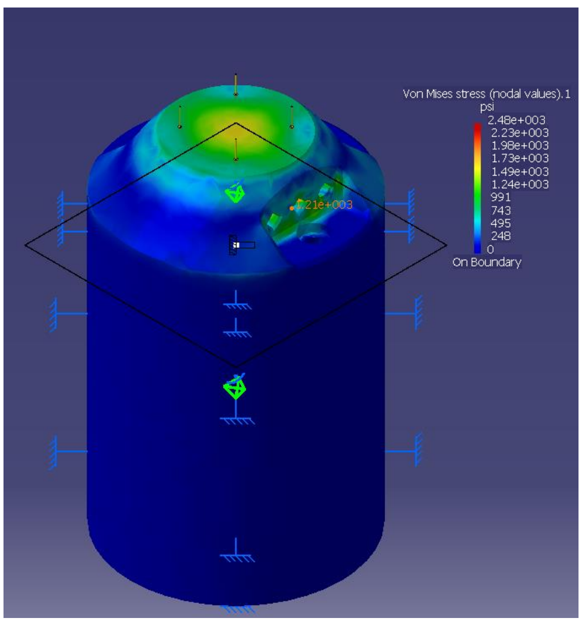



**Figure 13: Von Mises Stress**

In figure 15, FEA was conducted on the housing and cap using steel as the material and similar forces of midsized sedan acting directly on top of the cap. However, the weight of a car is distributed over the top surface of the cap. Thus, using the entire weight of 3000lbf gave ample assurance of safety. It was concluded, the highest level of stress (2480 psi) can be found near the holes of the LED lights. This data confirms the cap will not yield.

In order for the internal components to be safe, the cap should not be able to deflect more than 0.19685in downwards. This is critical for internal components within the cap and housing to be safe from damage.

Design and material selection with appropriate strength and stiffness is therefore required. After analysing the model, it was seen that the cap had a maximum deflection of 0.000482in. This confirms that the design and material selection for the housing and cap is acceptable. It can also be concluded that the internal components will be safe.

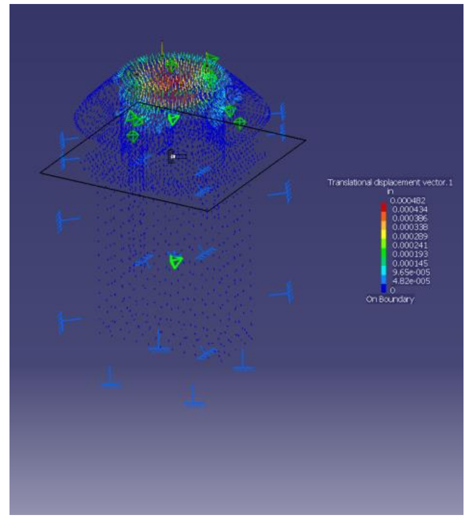


**Figure 14: Mesh Size vs Translational Displacement**

## IX. WIRING/PROGRAMMING

The lighting system will be connected directly to the existing traffic control system. The system is supplied by AC current from the power grid which will also power the Smartcross, shown in figure 17. Each smartcross system component (slave) will be individually wired to run from the master. These slave components will be positioned in 4ft increments along the span of an intersection. On average, a two way intersection is 50ft long thus, each intersection will receive nine Smartcross units which will all be connected through hard wiring and all will be powered by the current traffic system which is running on every intersection in New York City today.

Since LED lights are being used for the project, Arduino Uno has been found to be the best microcontroller that fits the needs. The main reason is that Arduinos are made to control sensors like LED lights; and one board is able to control up to 500 LEDs. Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software.

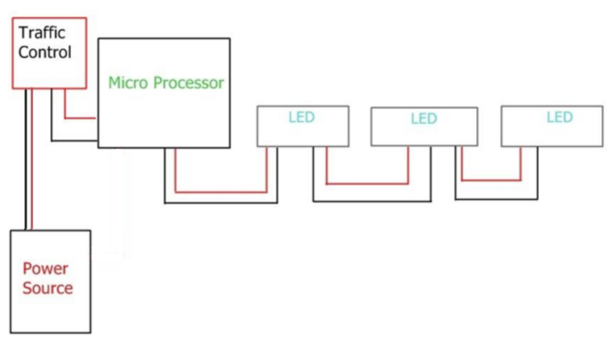



**Figure 15: Basic Wiring Schematic**

This was the easiest way possible to add small, bright RGB pixels (figure 9) to the Smartcross. These breadboard friendly LED's are easy to wire and they are flexible to mold around the circular inside of the cap. With two rows of 3 x 0.1" spaced header on each side for easy soldering, chaining and bread boarding, it was a little difficult to solder, the use of a fine tipped iron attachment was required. These ultra-bright LEDs have a constant-current driver cooked into each LED. The pixels are chainable as long as 500 LED's for one microcontroller thus, making it manageable to add as many LED's as the system requires. These pixels have full 24-bit color ability with PWM taken care of by the controller chip. Since the LED is so bright, less current and power is required to get the full use of these LED's. The driver is constant current helping the colors stay constant in a case of power surge, power outage for when a battery may control the system, a drop in current will not disturb the color output of the lights. Each pixel draws as much as 60mA (all three RGB LEDs on for full brightness white). Using ribbon cable these LED's can string to 6" apart which is ample distance as these units will be placed 4ft apart.

The Arduino Uno (figure 9) is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 programmed as a USB-to-serial converter.

The Arduino board and the LED's are connected together. Initially, the lights will only be solid lit as there is no code in the microcontroller, once the code the added, the lights will change according to the program. Soldering was the toughest part of the process as the soldering connections are very close together. The soldering had to be clean and precise to prevent any shorting.

The Arduino software was used for programming, which can be obtain from Arduino download page [3]. Arduino software syntax is similar to C/C++ and Java, but it is designed to be simple and easy to use. In order to start programming the Neopixel LED lights, we were able to download a library of codes from GitHub.com [4]. The library gave sample codes, which was modify to control the LED lights, as desired. Figure 6 shows part of the code that has been written for controlling 9 LED lights.

The library has sample codes, which we used to modify to control the LED lights. Figure 18 shows part of the code that has been written for controlling 9 LED lights. Each line represents a function for every LED, starting with LED 1 being 0 to LED 9 being 8. In order to control the color for the LEDs, values have to be entered from 0-150, 0 being off and 150 being fully on, in between the prentices after using the function "pixels. Color". The Neopixel LED lights use a combination of red, green and blue LEDs to display a variety of colors. In this code the first 3 LEDs are displaying only green light so red and blue are "0" and green is "150". The next 3 LEDs are displaying only red, now blue and green are "0" and red is "150". The last 3 are also displaying green so red and blue are "0" and green is "150". Now to make the LEDs flash, the function "delay ()" is added. In this case, the delay is 50 milliseconds. All LEDs are turned off for 50 milliseconds and turned on 50 milliseconds and this will continue. The next step for the programming is to switch the colors of the LEDs, so the red LEDs turn green and the green LEDs turn red. Once the LEDs are fully programmed, the final step will be to find a way to connect the microcontroller to the existing traffic light system.

```
void loop() {

    pixels.setPixelColor(0, pixels.Color(0,150,0));
    pixels.setPixelColor(1, pixels.Color(0,150,0));
    pixels.setPixelColor(2, pixels.Color(0,150,0));
    pixels.setPixelColor(3, pixels.Color(150,0,0));
    pixels.setPixelColor(4, pixels.Color(150,0,0));
    pixels.setPixelColor(5, pixels.Color(150,0,0));
    pixels.setPixelColor(6, pixels.Color(0,150,0));
    pixels.setPixelColor(7, pixels.Color(0,150,0));
    pixels.setPixelColor(8, pixels.Color(0,150,0));
    pixels.show();
    delay(50);
    pixels.setPixelColor(0, pixels.Color(0,0,0));
    pixels.setPixelColor(1, pixels.Color(0,0,0));
    pixels.setPixelColor(2, pixels.Color(0,0,0));
    pixels.setPixelColor(3, pixels.Color(0,0,0));
    pixels.setPixelColor(4, pixels.Color(0,0,0));
    pixels.setPixelColor(5, pixels.Color(0,0,0));
    pixels.setPixelColor(6, pixels.Color(0,0,0));
    pixels.setPixelColor(7, pixels.Color(0,0,0));
    pixels.setPixelColor(8, pixels.Color(0,0,0));
    pixels.show();
    delay(50);

};
```

**Figure 16: Modified Code**

## X. CONCLUSION

To conclude, a fully working prototype of lighting system was build. The prototype was designed using CATIA and later 3D printed. It houses an Arduino Uno microcontroller which controls the 9 LED lights. The LEDs either flash red lights towards pedestrians to get their attention and warn them if it's a "Don't Walk" sign or flash green if it's a "Walk" sign. At the same time, the LED lights flash current traffic signal towards oncoming traffic. FEA was done to prove that if an actual prototype was build out of steel, it would withstand a force of 3000lbf attacking down on the cap. FEA all showed that the deformation ranges from 0.00017inches to 0.00016inches, which is well in below the 0.19685inches stated in the engineering requirements.

When all components are complied, the final assembly of all the parts went together as seen on figure 20. When all parts are attached and tested, a fully functional prototype has been created and as seen in figure 21.

Figure 20: Final Assembly showing all the internal components

**Figure 21: Final Assembly Figure**

**Figure 22: Final prototype embedded to represent a road**


## XI. ACKNOWLEDGMENT

Firstly, we would like to give a special thanks to Dr. Yougashwar Budhoo for all his help, support and guidance throughout this project. Second, we would like to thank our chairman of engineering and technology at Vaughn College Dr. Hossein Rahemi, for his support in this project. Finally, we would also like to thank our colleague Jefferson Maldonado, who helped us get started with the programming.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