EML 4551 Senior Design Project

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REQUIREMENT FOR THE DEGREE OF
BACHELOR OF SCIENCE
IN
MECHANICAL ENGINEERING

GLOBOL BIKE: DESIGN OF A SUSTAINABLY ILLUMINATED BICYCLE
25% Senior Design Report

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This B.S. thesis is written in partial fulfillment of the requirements in EML 4905.
The contents represent the opinion of the authors and not the Department of
Mechanical and Materials Engineering.

Ethics Statement and Signatures

The work submitted in this B.S. thesis is solely prepared by a team consisting of John Goolcharan, Ximena Prugue, and Roxana Ruyani and it is original. Excerpts from others' work have been clearly identified, their work acknowledged within the text and listed in the list of references. All of the engineering drawings, computer programs, formulations, design work, prototype development and testing reported in this document are also original and prepared by the same team of students.

Roxana Ruyani	Ximena Prugue	John Goolcharan
Team Leader	Team Member	Team Member

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Abstract

Safety and visibility remains a primary concern among the cycling community, especially in the United States. As modern global societies focus more on sustainability and reduction of fossil fuel consumption, bicycles need to be multifunctional and safer for nighttime riding. Globol Bike is a student-driven senior design project focused on developing a bicycle prototype with a self-sustainable, illuminated frame. The novelty of the Globol design involves harnessing the mechanical energy generated by the pedaling of the cyclist. That mechanical energy will be utilized to power the LED lighting system and other possible auxiliary applications. A hub generator located on the front wheel will capture the mechanical energy and convert it to electrical energy used to provide the power input for the LED arrays. The proposed Globol bike design will consist of a frame made of clear composite tubing through which the LED light can shine. This design project is sponsored by Globol (Glowing While Mobile) founded by Duriel Taylor. The Globol project will present a novel bicycle prototype that increases cyclist visibility while providing a green and sustainable mode of safe transportation for the modern commuter.

1. Introduction

1.1 Problem Statement

According to the National Highway Traffic Safety Administration, a total of six hundred and thirty bicyclist deaths occurred in the United States in 2009. These deaths accounted for two percent of all U.S. traffic fatalities in that year alone. As stated in the 2009 Traffic Safety Facts released by the U.S. Department of Transportation, twenty-seven percent of cyclist fatalities occurred during the nighttime hours [3]. These statistics are only for American cyclists. Cyclist injury and fatalities are potentially greater in global societies that rely more heavily on bicycling as a primary mode of transportation. Increasing cyclist safety worldwide can profoundly affect modern daily life in many indirect ways. Feeling safer when cycling may cause drivers to rely more on their bicycles as a safe mode of transportation. This can reduce the consumption of fossil fuels and provide an inexpensive and fun method of exercise. Cyclist safety is an issue that can be dealt with on the design level. Increasing nighttime rider visibility is a main problem that the Globol Bike project seeks to address.

1.2 Motivation

The Globol project was the international desire to increase rider safety and allow bicycles to be further integrated in modern daily life. The Swiss design of the Stromer E-bike provided some inspiration for the energy capabilities and bicycle energy sustainability. The Stromer design is a popular example of an “e-bike”. Electric bicycles, commonly known as e-bikes, have an internal motor that can be used for propulsion to provide electric-assist for the rider. The Globol project is inspired by the Stromer e-bike, but it also offers something different to the cycling community. Globol deviates from the Stromer design by utilizing the pedaling mechanical energy for work instead of providing propulsion assistance to the rider.

The lighting system is powered entirely by the pedaling of the cyclist. The use of composite tubes in the frame allows for the bicycle to be lightweight yet strong. Composite materials also allow for a certain level of customization and flexibility of design. However, it is also possible to design an aluminum bicycle frame with cutouts to allow the light to escape and illuminate the bike. The final prototype design and frame material selection is still in progress.

The Globol project will involve building a prototype and performing adequate analysis on the lighting, structural and energy components of the bicycle. The finite element analysis software Abaqus FEA is utilized to perform structural analysis on the frame material. Analysis and testing was also performed on the LED's and electroluminescent components. The prototype adheres to the bicycle ASTM 08.10 standard series for design and ASTM f2711-08 for testing.

Auxiliary applications are possible, depending on the final prototype design and analysis. Such applications could involve including a USB port for charging devices, blinking turn signals for communicating with drivers and other cyclists, and harnessing the cycling power to charge batteries. Charging capabilities may be useful during the day when the frame does not need to be lit up. Also, the hub generators may need to be outfitted with capacitors so that the lights stay on when the wheels stop moving. Commercial production of the Globol bike is a future possibility. The ultimate goal of the Globol project is to make a functional prototype that supports the fun and sustainable nature of the cycling community while increasing safety for cyclists and drivers.

1.2 Literature Survey

The bicycle design was carefully optimized to ensure that the bike can successfully withstand a satisfactory load. This load was determined using international standards, to ensure that the bike can be sold in multiple countries; in this case the standard used was ASTM F2711-08. This standard is used to test and verify the strength of the bike frame under several conditions. Each condition that was tested required that the bike frame be fixed and subjected to a cyclic loading, whose number of cycles and magnitude is determined by Table 1 below. For the testing, condition three was identified as the possible worst case scenario for the types of conditions that the bike will be subjected to, which gives a Cyclic Tensile Load of 1200N and Cyclic Compressive Load of 600N which has to be applied for 50,000 cycles.

Table 1: Loading Conditions Defined By ASTM

Condition	Intended Use	Cyclic Tensile Load (N)	Cyclic Compressive Load (N)	Cycles (x1000)
0	Children's Bike	600	300	50
1	Paved Roads and Smooth Surfaces	600	600	100
2	Unpaved and Gravel Roads	800	600	50
3	Rough technical areas, unimproved trails, small jumps	1,200	600	50
4	Extreme Off-road	Undefined	Undefined	Undefined

The ASTM F2711-08 stipulates three test conditions that have to be performed. The results obtained from the tests have to be analyzed using mechanical engineering design principles and an appropriate safety factor will be chosen.

1. Horizontal Loading Durability Fatigue Test
2. Vertical Loading Durability Fatigue Test
3. Impact Strength Test

The Horizontal Loading Durability Fatigue Test is used to determine the fatigue failure mode in the front of the bicycle (Dwyer, 2012). The bicycle is loaded in the horizontal axis at the bottom of the front fork with the rear part of the frame constrained. The load applied to the bicycle in the horizontal frame will be according to Condition three in Table 1, Tensile Load of 1200N and Compressive Load of 600N for 50,000 cycles.

To Conduct the Vertical Loading Durability Fatigue Test the rear of the bicycle is restrained while allowing the front axle to rotate. While the bicycle is in this position the load is applied to a position behind the seat posts of the bicycle along the vertical axis. This load is that of Condition three in Table 1, Tensile Load of 1200N and Compressive Load of 600N for 50,000 cycles. This test verifies the loading of the frame for the rider (Dwyer, 2012).

The Impact Strength Test has the bicycle mounted and subject to a striker on a test fork attached to the front of the bicycle. The rear of the bicycle is restrained and the front axle is allowed to rotate. This test allows simulation and observation of stresses that can occur due to impact on the front fork (Dwyer, 2012).

These tests are important because the principle of superposition can be used to analyze several loading cases. The three loading cases define the three specific loads that the bicycle is subjected to, the loading cases that the bicycle is subjected to can be determined to be a combination of each one of the cases. This is consistent with the Principle of Superposition of Waves (Freeman et al, 2008). The traditional Principle of Superposition is based on the assumption that graphs are linear functions (Maslov et al, 1987). Therefore, the final values for failure, when dealing with a combination of loading conditions, can be obtained by superimposing one of the result cases upon the results of the other cases.

The results obtained from the tests prescribed by the ASTM standards were analyzed using Mechanical Engineering Design Principles. When load is applied to the bicycle the frame will begin to store energy and become deformed (Budynas, 2012). This Deformation is related to the Strain Energy. The strain energy can be observed for failure by utilizing Von Mises Theory or Maximum Distortion Energy Theory of Failure. "It predicts the failure of a specimen subjected to any combination of loads when the strain energy per unit volume due to shear of any portion of the stressed member reaches the failure value of strain energy per unit volume due to shear as determined from an axial or compression test of the same material" (Farooq, 2011). The Von Mises Stress Requirement is seen in Equation [1]. Fatigue life can be observed by a system of factors based on several factors, seen in Equation [2]. Fatigue life calculations observe life for cyclic loading conditions (Budynas, 2012).

$$\sigma_{vm} = \sqrt{\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_1-\sigma_3)^2}{2}} = \frac{S_y}{n} \qquad [1]$$

Where, σ_1 σ_2 σ_3 are the Principle Stresses on the Design

σ_{vm} is the Equivalent Stress

S_y is the Yield Strength

n is the Safety Factor

$$S_e = k_a k_b k_c k_d k_e k_f S_e' \qquad [2]$$

Where, S_e is endurance limit for critical load for the system

S_e' is test specimen endurance limit

k_a is the surface condition modification factor

k_b is the size modification factor

k_c is the load modification factor

k_d is the temperature modification factor

k_e is the reliability factor

k_f is the miscellaneous effects modification factor

The above equations provide a measure of complexity when subjected to three dimensional problems with multidirectional Forces and Pressures applied. This can be simplified by using the principles of Finite Element Analysis. Finite Element Analysis allows Engineers the opportunity to reduce the size and complexity of a problem by breaking up the design into smaller parts. Each part will be used to determine the solution as if it were one complete body (Widas, 1997). Computational Software such as SolidWorks, analyze designs by utilizing this principle. In computational software the program creates a tetrahedral 'mesh' which means that it breaks up the body into small parts (Widas, 1997). The fact that the design is reduced into smaller parts will introduce a measure of uncertainty into the calculations and can lead to increased errors, therefore it is important to allow for the optimum number of elements to be chosen. For computational software, there is a method that is used to determine the optimal number of elements. This method is called a Convergence Study (Gobbert et al, 2010). To perform a convergence the value of a parameter which always converges, i.e. a parameter which will always go towards a fixed absolute value, will be observed. In the case of Static Analysis SolidWorks the value that is used for the Convergence Study is the Resultant Displacement is the parameter that will always converge. The mesh sizes are to be changed repeatedly until the values of Resultant Displacement approach a steady value, at this point, the results have converged and the other parameters that can be obtained from that simulation are taken to be accurate.

2. Conceptual Design

The core concept behind Globol is to create a clear bike that is illuminated by LEDs with power that is self-generated by the cranking motions of the bicycle frame.

2.1 Material Selection

The preliminary design choices to build a clear bike were Trivex, S-Glass, E-Glass, polycarbonate, and acrylic. Polycarbonate and acrylic were deemed unsuitable materials because they would make the bicycle very uncomfortable to ride and would be very heavy and cumbrous. S-glass and E-glass are difficult to manufacture into tubes and are not transparent, but cloudy. Trivex is the most viable alternative, but it is expensive and patented by PPG, which makes it difficult to research the material properties and manufacturing processes.

2.2 Frame

The frame will be designed for commuting. This means it needs to be comfortable, has a gear ratio that allows for quick acceleration and a high cruising speed while maintaining a lightweight structure to be easily transported. We are using a road bike design, which has the rear dropouts that are designed for a derailleur hanger and fits 700c wheels.

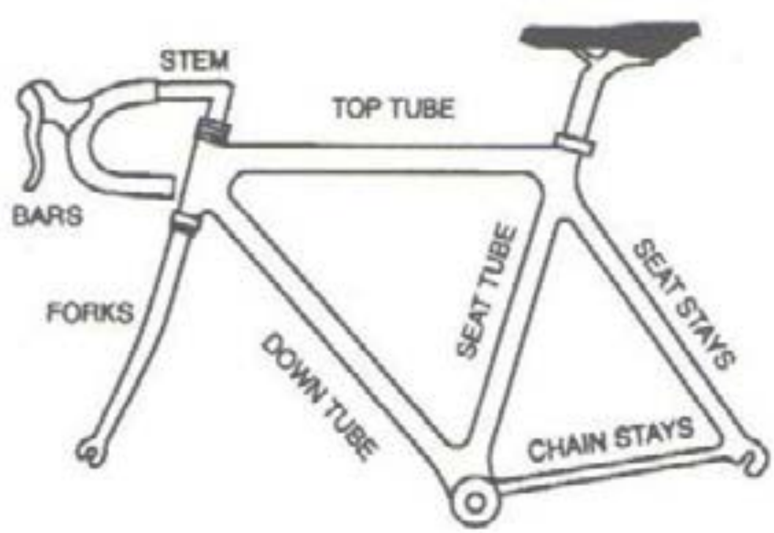

Figure 1: Bicycle Components Diagram. (Bicycle Buzz, 2012)

Figure 2: (Above) Basic Bicycle Frame CAD Model

2.2.1 Aluminum Frame with Slits

The shape of the frame is considered diamond shape, or double-triangle, and consists of four tubes: the head tube, top tube, down tube and seat tube. The rear triangle consists of the seat tube joined by paired chain stays and seat stays. The strength of the design comes from the triangle shapes that make up the diamond design.

The frame material will be Aluminum 6061 because it is lightweight, strong, and makes for a comfortable ride. Other materials that were considered were titanium, carbon fiber, and steel. Titanium is expensive—it can cost up to 15 times more than steel—and is difficult to manufacture. Steel is stronger than aluminum, but is significantly heavier than aluminum. Carbon fiber is also expensive and would not be suitable to make slits in the frame. Aluminum is relatively soft. This makes it easier to manipulate into tubes of varying thicknesses and shapes. It is also much less expensive than carbon-fiber and titanium, which would make the bicycle easier to market to young riders. Although aluminum is not as light as carbon, some major bicycle manufacturers, such as Jamis, have been able to make aluminum frames as light 1,150 grams. Aluminum tubes will have much larger thickness than steel tubes, but they are still lighter.

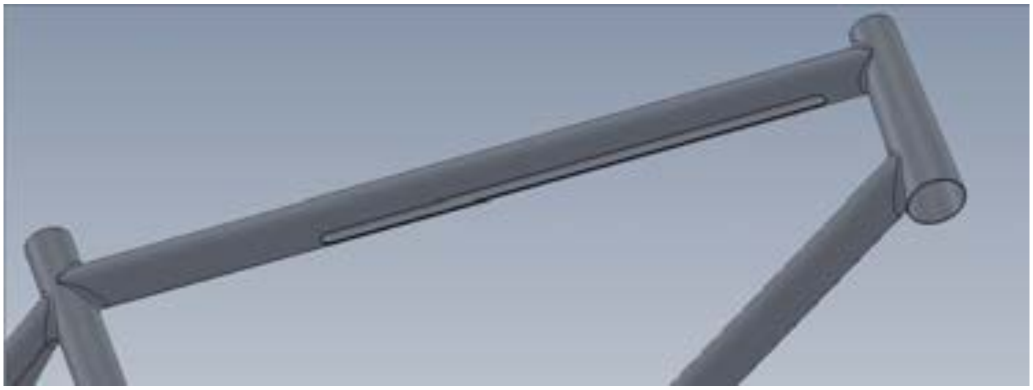

Figure 3 Close-up of top tube slit of aluminum frame

The frame will have slits for LEDs along the head tube, down tube, and seat tube. They will also have smaller slits along the seat stays for LED turning signals. Finite element analysis will be performed through simulations using Solidworks in order to determine failure mechanisms and the required thickness of the tubing.

2.2.2 Aluminum "Half Moon" Cross Section

Another design alternative for the frame was to have a "half-moon" cross section on the top tube in order to fill the other half with a clear plastic. The top half of the moon would serve as the structural support so that the LEDs could be mounted on the top half facing downward to illuminate the drop tube and seat tube. This design is not likely to be utilized since the factor of safety for preliminary FEA simulations returned a factor of safety below one.

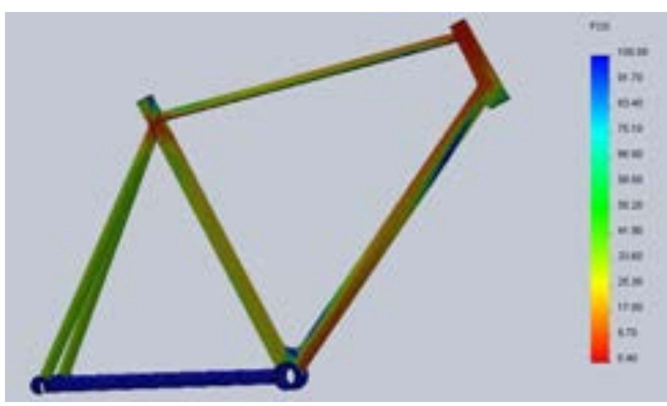

Figure 4: Solidworks Simulation of Half Moon Cross Section

2.3 Energy Generation

2.3.1 Hub Dynamo

The proposed bicycle prototype design will involve the utilization of hub generators to capture the mechanical energy generated by the rotation of the wheels. The particular hub generators that were investigated for the proposed Globol prototype design is the SONdelux Dynohub and Shimano dynohubs. The SONdelux Dynamo hub is 390 grams in weight compared to a similar, yet older model, the Shimano hub, which is 575 grams. Both generators produce an output of three watts. The thirty-two spoke-hole design is chosen over the thirty-six spoke-hole design to allow for less weight. The SONdelux hub generators is installed in the front wheel and rear wheel. Utilizing two hub generators will essentially double the power output, which will allow for the design to sustain more luminescence in the lighting system. The SONdelux hub is commercially available, and the wheel and hub generator was purchased as one preassembled piece.

Figure 5: SONdelux Dynohub Bicycle Wheel Generator

Figure 6: Shimano Nutted Dynohub

Table 2: Specifications for the SONdelux Dynohub Bicycle Wheel Generator

Electrical power output	6 volts/ 3 Watts
Energy efficiency	65% at 9 mph in 622 (700 c) wheel
Weight	390 g

	Shimano NX-30	Shimano DH-3N70/71/72/80 & Alfine	Schmidt SONdelux
Efficiency at 15 km/h, (about 10 mph)	49%	53%	64%
Energy required of the rider to rotate the hub when the lights are turned off at 30 km/h.	6.5 watts	2.2 watts	1.5 watts
Weight	720 grams	680 grams	575 grams

Table 3 Efficiency Comparison of Hub Dynamos

The mechanical cranking technology of the hub generator is coupled with LEDs and electroluminescent wires to illuminate the entire bicycle frame. Electroluminescent (EL) panels are used to outfit the prototype with blinking turning signals. Electroluminescent components are safe and convenient methods of providing light on the prototype frame. The EL panels and wires will be electrically connected to the hub generators. The mechanical energy of the pedaling is converted to an electric current which is fed directly into the lighting system. The turning signals will be controlled using a PIC16F690 microcontroller programmed with the use of the mikroBasic compiler. Integration of simple switches located on the handlebars provide an interface between the rider and the turn signals. The utilization of turn signals further increases the visibility of the rider during both nighttime and daytime hours. Blinking turn signals on the Globol bike allows riders to efficiently and safely communicate to drivers and fellow cyclists.

2.3.2 Solar-powered fenders

Another addition to energy generation being considered is installing flexible solar panels to the fenders of the bicycle. This can allow for a passive energy generation that could be used to charge cell-phones, mp3 players, or potentially iPads and other electronics. Seamlessly adding a solar panel to the fenders of a bicycle has never been done before, which can be innovative and a selling point for our investor if the energy generation of the panels is successful.

The fenders will add weight to the bicycle, however, so we will be testing how much power can be generated from a sunny day with the solar panels on the fenders to determine if the additional power generation is worth the additional weight.

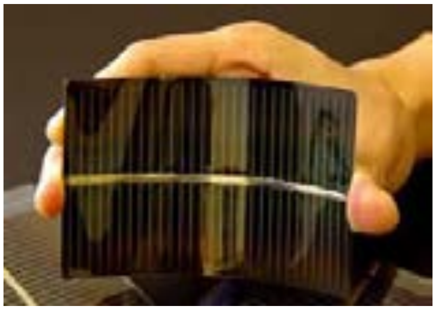

Figure 7: Flexible Solar Panel

2.4 Electroluminescence

Electroluminescence is an optical phenomenon and electrical phenomenon where a materials emits lights when an electric current is applied, or in the presence of a strong electric field. Electroluminescence is the result of radiative recombination of electrons and holes in a materials, usually a semiconductor. In radiative recombination, or band-to-band recombination, the electron in the conduction band recombines in a hole in the valence band, giving off energy as a photon. The emitted photon has an energy similar to the band gap and is therefore only weakly absorbed such that it can exit the piece of semiconductor.

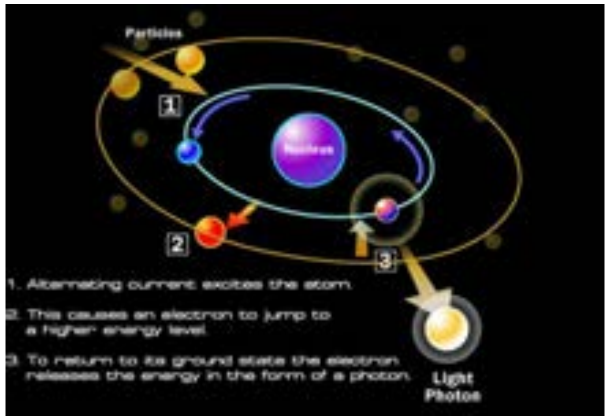

Figure 8: How Electroluminescence Works at the Sub-Atomic Level (Photo by lumilor.com)

Figure 9: (Right) Flexible electroluminescent (EL) panel.
(Image taken from adafruit.com)

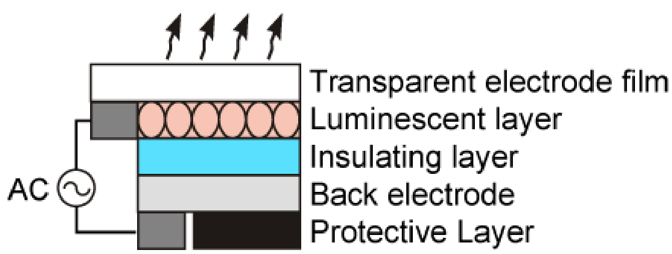

Figure 10: Schematic for layers within electroluminescent panel.
(Image taken from globalspec.com)

3. Prototype Design: Major Components

Our final design will use electroluminescent paint on an aluminum frame bike that with be powered by generators attached to the bicycle. Darkside Scientific, a startup based in Medina, Ohio, patented Luminor™, an electroluminescent paint that can be directly applied to the aluminum frame.

3.1 Structural Analysis of Frame

For the scope of the project, the existing structure of a bicycle is used, which means that the frame will have already met standards for safety and for the load that would be placed on the frame. This initial testing performed by the manufacturer was inadequate for the project as the frame will have only been affected by the loads described in ASTM F08.10 and ASTM F2711-08 Series. These ASTM standards maintain an internationally recognized definitive for bicycle design and testing. Before the manufacturer is allowed to market the frames the tests prescribed in the standards will have to be performed ensuring public safety. These tests indicate specific loading conditions for the bicycle frame.

The project entailed the addition of auxiliary equipment to the bicycle frame, which will present an additional loading condition on the frame. The addition of parts such as the Hub Generator and other auxiliary parts applied additional loads to the system. The additional loads were small compared to the loads that the frame was subjected to for the initial testing using the ASTM standards, however, the loads will still have an impact on the frame because of the point of application. The Hub Generator had the load applied to the bottom of the frame, where it is connected to the wheels, while the other applications are placed directly on the frame itself. The potential for failure was based on the fact the Hub Generator was placed at a point which is under a large amount of stress due to the vibration of the wheels, reaction forces while the rider goes along and the transmitted load from the rider. Furthermore, the other auxiliary applications that were mounted unto the frame were of concern because it presented a potential for shear stresses and bending moments within the frame. This load caused the behavior of the frame to be altered as the frame now had to support the rider as well as these loads.

The structural testing was performed using the ASTM standards for bicycle design and testing with the addition of the new loads to the frame. The testing was done using simulation software and testing the actual bike frame. The software was used by setting up a model of the frame of the bicycle and the preloads, the Hub Generator and the auxiliary applications were applied before the loading conditions as prescribed in the ASTM standards were performed. Once this testing was performed the actual frame was tested to determine whether the conditions were valid.

3.2 Hub Generator

The SONdelux hub generator is used due to a lightweight design with higher power output efficiency. The SONdelux is 185 grams lighter than its heavier Shimano counterpart. Only a front generator is used because it delivers sufficient power for approximately 100 square inches of Lumilor electroluminescent paint.

3.3 Electroluminescent Paint

Lumilor™ is a multi-layer coating system that fully applied is about 0.003” (0.1mm) thick. On top of this coating, an additional topcoat is applied, typically a tinted clearcoat. The choice of topcoat is up to the user, and such factors as sheen elasticity, weather protection, and impact resistance will determine which topcoat should be used and the ultimate thickness of the coating system. It’s comprised of an environmentally friendly aqueous based polymer blend, rendering it cleaner than a large majority of paints on the market. Its user friendly as it requires no special tools or expensive equipment to apply. Lumilor™ is safe and cool to the touch, which makes it ideal for consumer use. It also looks like regular paint in light.

The life of the paint depends on the color selected, and the frequency and voltage of the source. Charging and discharging does not impact the life of the paint, only the total hours that it is powered. Lumilor™ requires an alternating current field to operate and takes 0.7 mA of current to charge one square inch of paint. The aluminum will need to be primed first to insulate it electrically before the Lumilor™ paint is applied.

Figure 11: Sample Painted with LumiLor Electroluminescent Paint (Image taken from lumilor.com)

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4. Timeline for Project

4.1 Gantt Chart

The Gantt chart for the Globol project timeline is shown below. The project timeline shows the major milestones of the project starting in the beginning of the Fall 2013 semester and ending at the end of the Spring 2014. This Gantt chart will be used to ensure that all of the important goals of the Globol Project were competed in a timely and efficient manner.

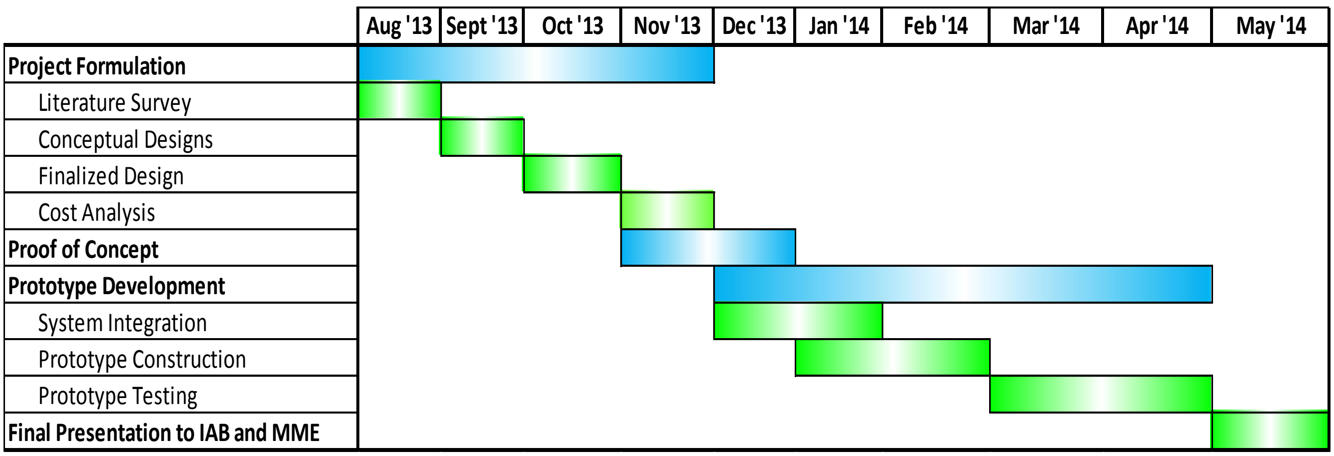

Figure 12: Gantt Chart for Globol Project Timeline

4.2 Team Member Responsibilities

The responsibilities of each team member is listed in the table found below. Please note that each team member contributed equally to all of the reports and presentations for this senior design project. The Globol project is very much a collaborative effort of the three students and their senior design advisor Dr. Benjamin Boesl.

Table 4: Roles and Contributions of Each Team Member on the Globol Project Student Design Team

Team Member	Roles and Contributions
Roxana Ruyani	Team Leader
	Energy generation and integration
	Organization and coordination of student design team.
	Point of contact for supply and component orders
Ximena Prugue	Lighting system design and integration
	Point of contact for Darkside Scientific and LumiLor labs
	Globol Project Poster
John Goolcharan	Materials analysis
	FEA and Structural Analysis
	Ensuring Globol prototype adheres to bicycle design standards

5. Cost Analysis

5.1 Time Cost Analysis

The time costs analysis includes the total individual hours spent by the student design team on the Globol Project. The total human hours spent were quantified to calculate the human capital costs of the project. The human capital costs estimates the cost of the engineering services rendered if this project was completed by paid engineers. This value does not contribute to the actual cost of the Globol project, because this project was completed by a student design team as a thesis requirement. The engineering services cost was estimated as $25 per hours for a junior mechanical engineer making a gross annual income of $50,000. The tables below list breakdowns of the actual hours spent on the Globol project by each team member during the Fall 2013 and Spring 2014 semesters.

Table 5: Time Reporting Breakdown for Student Design Team During Fall 2013 Semester

Time Reporting: Fall 2013 Semester							
Date	Time (hrs)	Date	Time (hrs)	Date	Time (hrs)	Date	Time (hrs)
Group Meetings		**Ximena**		**Roxana**		**John**	
27-Aug	0.5	27-Aug	2.5	27-Aug	0.5	27-Aug	0.5
3-Sep	1.5	3-Sep	1.5	3-Sep	1.5	3-Sep	1.5
9-Sep	1.5	9-Sep	1.5	9-Sep	1.5	9-Sep	1.5
26-Sep	1.5	26-Sep	1.5	26-Sep	1.5	26-Sep	1.5
10-Oct	0.5	10-Oct	2.5	10-Oct	1	10-Oct	3
17-Oct	1	17-Oct	2	17-Oct	2	17-Oct	1
24-Oct	0.5	24-Oct	7.75	24-Oct	7.75	24-Oct	5
31-Oct	0.5	31-Oct	2	31-Oct	2	31-Oct	1
7-Nov	0.5	7-Nov	2	7-Nov	2	7-Nov	2
14-Nov	0.5	14-Nov	5	14-Nov	4	14-Nov	4
21-Nov	0.5	21-Nov	3	21-Nov	5.5	21-Nov	4
28-Nov	0.5	28-Nov	2	28-Nov	2	28-Nov	2
5-Dec	0.5	5-Dec	2	5-Dec	2	5-Dec	2
Total hours	10	**Total hours**	35.25	**Total hours**	33.25	**Total hours**	29

Table 6: Estimated Time Reporting Breakdown for Student Design Team During Spring 2014 Semester

Time Reporting: Spring 2014 Semester							
Date	Time (hrs)	Date	Time (hrs)	Date	Time (hrs)	Date	Time (hrs)
Group Meetings		**Ximena**		**Roxana**		**John**	
9-Jan	0.5	9-Jan	2.5	9-Jan	2.5	9-Jan	2.5
16-Jan	0.5	16-Jan	2	16-Jan	2	16-Jan	2
23-Jan	0.5	23-Jan	2.5	23-Jan	2.5	23-Jan	2.5
30-Jan	0.5	30-Jan	2	30-Jan	2	30-Jan	2
6-Feb	0.5	6-Feb	2	6-Feb	2	6-Feb	2
13-Feb	0.5	13-Feb	2	13-Feb	2	13-Feb	2
20-Feb	0.5	20-Feb	2	20-Feb	2	20-Feb	2
27-Feb	0.5	27-Feb	2	27-Feb	2	27-Feb	2
6-Mar	0.5	6-Mar	2	6-Mar	2	6-Mar	2
13-Mar	0.5	13-Mar	2	13-Mar	2	13-Mar	2
20-Mar	0.5	20-Mar	2	20-Mar	2	20-Mar	2
27-Mar	0.5	27-Mar	2	27-Mar	2	27-Mar	2
3-Apr	0.5	3-Apr	2	3-Apr	2	3-Apr	2
10-Apr	0.5	10-Apr	2	10-Apr	2	10-Apr	2
17-Apr	0.5	17-Apr	2	17-Apr	2	17-Apr	2
24-Apr	0.5	24-Apr	2	24-Apr	2	24-Apr	2
Total hours	3.5	**Total hours**	33	**Total hours**	33	**Total hours**	33

Table 7: Total Engineering Hours for Fall and Spring Semesters

	Fall 2013	**Spring 2014**
Engineering Hours	74.25	102.5

Please note that the dates were simplified on a weekly basis. The hours listed for those dates are the sum of hours for each week. Also, the time reporting for the Spring 2014 semester is an estimation, because this is a partial report that was written in November of 2013.

5.2 Project Cost Analysis

The monetary cost analysis for the Globol Bicycle Design project is detailed in the table shown below. The table lists the total project cost with and without the engineering costs. The actual value is the cost without engineering services, because the student design team was completing this project as a fulfillment of their undergraduate degrees. However, it is imperative to estimate the engineering cost if this project was completed by a team of engineers. Therefore, the total cost of the project is estimated to be $4,150.99.

Table 8: Estimated Monetary Cost Analysis for Globol Design Project

Project Section	Item	Cost
Materials and Components	LED Components	$226.78
	21 Speed Road Bike	$302.86
	Bicycle Fender Set	$41.57
	Carbon Fiber Tube	$34.44
	Polycarbonate Tube	$8.36
	Aluminum Tube	$23.38
	SONdelux Hub Generator with Wheel	$403.60
	LumiLor Electroluminescent Paint Sample	$300
	Connectors for LumiLor Sample	$50
	Painting prototype by LumiLor Labs	$1,500
	Shipping prototype to LumiLor Labs	$50
	Future Miscillaneous Prototype Components	$500
	Future Bicycle Mechanic Services	$500
Reports and Presentation Materials	Report Printing Costs	$130
	Poster Printing Costs	$80
Engineering Costs	Fall 2013 Semester	$1,856
	Spring 2014	$2,563
	Total Project Cost (Without Engineering Costs)	$4,150.99
	Total Project Cost (With Engineering Costs)	$8,569.74

5.3 Prototype Cost Analysis

The prototype cost is the sum of the materials and components, which comprises of most of the total project cost. The total prototype cost is estimated to be $3,940.99. The total project cost is estimated at $4,150.99, so approximately 95% of the project cost will be invested into building the Globol bicycle prototype. Currently, the most costly portion of building the Globol prototype is painting the frame with the Lumilor™ electroluminescent paint. The vendor that created the Lumilor™ paint, Darkside Scientific, provided a quote of $10-$15 per square inch to apply the Lumilor™ electroluminescent coating system to the Globol bicycle prototype. It is estimated that the surface area of the bicycle frame that will be painted is approximately 100 square inches. The calculation of the estimated cost of painting the prototype uses the upper limit of the quote provided by Darkside Scientific, resulting in an estimated cost of $1,500 to apply the Lumilor™ paint to the bicycle prototype. The cost of painting the frame is about 38% of the prototype cost and 36% of the total project cost. The Lumilor™ paint is costly but well worth the price, because the electroluminescent frame is one of the primary components of the Globol bicycle.

5.4 Project Funding

This project was sponsored by the founder of the Glowing While Mobile Project, Duriel Taylor. Mr. Taylor provided $14,000 of funding to Florida International University as a donation to sponsor the design and implementation of ideas for the Globol Bicycle Project. The total projected project cost of $4,150.99 proves that the student design team will complete the Globol project well within the allotted budget. The total project cost with engineering servicers would have been $8,569.74. So, the project would remain within the budget even if it had been completed by a team consisting of three design engineers grossing an hourly income of $25 or $50,000 annual salary.

6. Plan for Tests on Prototype

The Globol bicycle prototype will undergo extensive testing to analyze the functionality and safety of the design. Some preliminary tests will be performed before building the bicycle prototype. The design team will perform power output testing of the SONdelux dynamo hub generator to determine the wattage and voltage supplied by the hub generator. The SONdelux dynamo hub specs list the output of the hub generator as 6 volts and 3 watts. These specs will be verified with power output testing. The team will also perform power requirement testing of the electroluminescent frame and the Lumilor™ sample provided by Darkside Scientific. These tests will ensure proper system integration.

Safety is the primary ultimate goal of the Globol project, so structural analysis of the prototype will performed. The team will perform FEA analysis on a computer-rendered model of the aluminum bicycle. The software Abaqus FEA will be used to perform this analysis. The goal of this structural analysis is to ensure that the Globol bicycle prototype satisfies the loading conditions stipulated in the ASTM F2711-08 Standard Test Methods for Bicycle Frames. The Globol design team strives to create a safe and functional bicycle that meets proper safety guidelines and standards.

7. Conclusion

The primary goal of the Globol Bike project is the development of a fully functional, self-sustained illuminated bicycle that is safe to ride and adheres to current design and testing standards. The commercialization and mass market production of the Globol bike is a future possibility, pending the development of an injection mold for the frame if the composite prototype is used. The cost of designing and producing an injection mold is high, however it is expected that the sales of a mass-produced Globol bike will return the initial investment. This design project will also prove to be immensely useful as a learning experience for the student design team. The construction of the Globol prototype will allow the student engineers to improve techniques in structural analysis, hands-on skills, electrical wiring, additive manufacturing and prototype development. Furthermore, the Globol student design project will be successful in contributing towards to improvement of sustainability and safety within the cycling community.

8. References

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9. Appendices

Appendix A: Acknoledgements

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