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# Shell-Eco Marathon
# Final 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 Alan De La Paz, Daniel Duncan, and Alejandro Parjus 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.

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**Abstract**

This project is an exercise by our team, Dynamic Engineering Solutions, in an effort to produce a highly efficient vehicle capable of competing in the 2014 Shell Eco-Marathon. This report will demonstrate the need for such an efficient vehicle, while detailing in great length various design possibilities involved in such an effort. Many properties including: material types, aerodynamic profile, weight distribution, and engine efficiency will be thoroughly researched and evaluated for this project. Our team will apply any relevant theories and practices taught at university to an actual real world design and fabrication process. In short, our goal is to reach maximum efficiency not only in vehicle design, but also in the fabrication process.

## 1 Introduction

### 1.1 Problem Statement

There has been a trend in recent years by manufacturers and regulators alike to increase motor vehicle fuel efficiency and environmental impact. More efficient vehicles will put less stress on sensitive oil distribution networks, will help to conserve the limited fossil fuel reserves, and also drive vehicle sales in the marketplace.

Possibly one of the greatest challenges facing the next generation of engineers is how to cope with the possibility of peak oil production. New technological advances must be applied to motor vehicle design in an effort to conserve the limited natural resources of the planet. This will help insure a smooth transition to the post-fossil fuel era.

## 1.2 Motivation

The motivation for this project came from the desire of not only doing research and producing an optimal vehicle design, but actually gaining hands on experience in producing a fully functional high efficiency vehicle. It is an enticing prospect to test and compete with our product versus other designs. As engineers it is our duty to drive innovation through increasingly superior designs.

## 1.3 Literature Survey

The modern industrial economies of the world have become virtually dependent on fossil fuels for their transportation purposes. The transportation sector in the US is the largest consumer of oil.[1] Many emerging markets like China and India are forecasted to consistently increase their oil consumption in the next few years, with transportation accounting for the largest of percentage of consumption.[2] This shows the strong relationship between oil consumption and transportation.

Many scientists have tried to predict a phenomenon known as peak oil. This is the point where oil production ceases to increase and begins contracting. Marion King Hubbert used a graphical method matching production rates over time to a bell curve.[3] Peak oil has been predicted to happen within the next few years or may even have already happened.[3]

It is important to note that oil demand is increasing, while oil is a finite resource with a finite production capability. In order to meet a sustainable balance more efficient vehicles that use less fossil fuel must be produced. This is one of the goals of the Shell Eco-marathon: to encourage the exploration of more fuel efficient vehicles.

The area of research involving fuel efficient vehicles can be demanding, but at the same time it can very rewarding both financially and environmentally. Our task of developing a high efficiency motor vehicle relates directly to the aforementioned problem of oil supply.

## 1.4 Discussion

The Shell Eco-Marathon is the perfect opportunity for our team to apply our engineering knowledge to a real world problem. The straightforward rules and regulations give an equal chance for all competing teams to demonstrate their engineering prowess. Our team is going to take advantage of this opportunity to not only apply our skills at research and design but also learn hand on fabrication techniques.

# 2 Project Formulation

## 2.1 Overview

In order to come to a decision for this vehicle many factors must be taken into consideration for building. Some of the major factors that rest upon us are the aerodynamic shape of the vehicle and the total weight of the vehicle. Many other factors such as a fuel efficient engine and driver skills are also a limiting factor but not as important as the first two mentioned. A great aerodynamic shape of the vehicle would provide great fuel efficiency since the vehicle would cut through the surrounding air like a hot knife through butter. To attain a good aerodynamic shape a good drag to weight ratio must be applied. In simple terms less drag would create a sleeker smoother run of the vehicle much like an arrow from an archer. The other limiting factor is its overall weight. Creating a light weight model would significantly increase its efficiency. Plans for reduction of weight would call for a light weight cassis and driver. After conducting a little research into the designs of commonly used marathon vehicles and comparing their uses with those that this vehicle would need, it was decided that a conventional lightweight design would be used. Being that this car would need to drive at least fifteen miles per hour of driving, a conceptual design seemed like the most feasible option.

## 2.2 Project Objectives

A. Ensure all engineering ethics are followed during project planning, construction, assembly, and documentation.

B. Complete the project with life-long learning and global learning impacts in mind.

C. Focus not just on engine power and weight, but also on aerodynamics and overall weight distribution.

D. Build an optimized vehicle that will produce the desired results.

## 2.3 Proposed Design

Since looking at many past models and comparing between many designs, a conceptual standard design was chosen. The conceptual design is a lightweight, low center of gravity car that can glide through the air. Lightweight aluminum cassis would be our primary metal of choice with a fiberglass outer body, this decision would create a very lightweight vehicle and the construction of these materials would have a low center of gravity. Lastly a gasoline engine must be in place for the whole car to move. The engine selection is very critical for are analysis and the most modern fuel efficient engine with a low displacement in the pistons and volume would be best fit for our vehicle. Below is a figure displaying the likelihood of our design.

**Figure 1: Proposed Design**

## 2.4 Design Specifications

**Vehicle Design**

A. During vehicle design, construction and competition planning, participating Teams must pay particular attention to all aspects of safety, i.e. Driver safety, the safety of other Team members and spectator safety.

   i) Prototype vehicles must have three or four running wheels, which under normal running conditions must be all in continuous contact with the road.

   ii) UrbanConcept vehicles must have exactly four wheels, which under normal running conditions must be all in continuous contact with the road. A fifth wheel for any purpose is forbidden.

B. Aerodynamic appendages, which adjust or are prone to changing shape due to wind whilst the vehicle is in motion, are forbidden.

C. Vehicle bodies must not be prone to changing shape due to wind and must not include any external appendages that might be dangerous to other Team members; e.g. pointed part of the vehicle body. Any sharp points must have a radius of 5 cm or greater, alternatively they should be made of foam or similar deformable material.

D. The vehicle interior must not contain any objects that might injure the Driver during a collision.

E. Windows must not be made of any material which may shatter into sharp shards. Recommended material: Polycarbonate (e.g. Lexan)

F. ) Any cover of the energy compartment (engine / motor / transmission / battery, etc.) should be easy to open for quick inspection access.

G. All parts of the drive train, including fuel tank, hydrogen system components, etc. must be within the confines of the body cover.

H. All objects in the vehicle must be securely mounted, e.g. bungee cords or other elastic material are not permitted for securing heavy objects like batteries.

**Chassis Monocoque Solidity**

A. Teams must ensure that the vehicle chassis or monocoque is solid.

B. The vehicle chassis must be equipped with an effective roll bar that extends 5 cm around the driver's helmet when seated in normal driving position with the safety belts fastened.

C. This roll bar must extend in width beyond the driver's shoulders when seated in normal driving position with the safety belts fastened.

D. Any roll bar must be capable of withstanding a static load of 700 N (~ 70 kg) applied in a vertical, horizontal or perpendicular direction, without deforming (i.e. in any direction).

E. The vehicle chassis or monocoque must be wide and long enough to protect the driver's body in case of a frontal or lateral collision.

**Propulsion and Energy Storage System Isolation:**

A. A permanent Bulkhead must completely separate the vehicle's propulsion and energy storage systems from the driver's compartment.

B. This bulkhead must be of fire retardant material and construction.

C. In closed-top Prototype vehicles and in all UrbanConcept vehicles, the bulkhead must effectively seal the driver's compartment from the propulsion and fuel system.

D. In open Prototype vehicles the bulkhead must extend at least 5 cm above the highest point of the propulsion and fuel system or the driver's shoulders – whichever is the highest.

E. The bulkhead must prevent manual access to the engine / energy compartment by the driver.

**Visibility**

A. The Driver must have access to a direct arc of visibility ahead and to 90° on each side of the longitudinal axis of the vehicle. This field of vision must be achieved without aid of any optical (or electronic) devices such as mirrors, prisms, periscopes, etc. Movement of the Driver's head within the confines of the vehicle body to achieve a complete arc of vision is allowed.

B. The vehicle must be equipped with a rear-view mirror on each side of the vehicle, each with a minimum surface area of 25 $cm^2$ (e.g. 5 cm x 5 cm). The visibility provided by these mirrors, and their proper attachment, will be subject to inspection. An electronic device must not replace a rear-view mirror.

C. An Inspector will check visibility in each of the vehicles in order to assess on-track safety. This Inspector will check good visibility with 60 cm high blocks spread out every 30° in a half-circle, with a 4 m radius in front of the vehicle.

D. For UrbanConcept vehicles wet weather visibility is also mandatory (Article 52:)

**Safety Belts**

A. The Driver's seat must be fitted with an effective safety harness having at least five mounting points to maintain the Driver in his/her seat.

B. The mounting point(s) for the crotch strap(s) must be below the Driver's torso to prevent the Driver from slipping forward.

C. The 5 independent belts must be firmly attached to the vehicle's main structure and be fitted into a single buckle, specifically designed for this purpose.

D. The safety harness must be worn and fastened at all times when the vehicle is in motion.

E. The fitness for purpose of the harness and its fitting will be evaluated during technical inspection. For Prototype cars this will be done by raising the vehicle with the Driver on board using the safety harness for suspension.

F. The safety harness for prototype vehicles must withstand a force of at least 1.5 times the Driver's weight.

**Clutch and Transmission**

A. All vehicles with internal combustion engines must be equipped with a clutch system.

B. For centrifugal / automatic clutches the starter motor speed must always be below the engagement speed of the clutch.

C. For manual clutches the starter motor must not be operable with the clutch engaged. An interlock is required to facilitate this functionality.

D. The installation of effective transmission chain or belt guard(s) is mandatory.

**Dimensions**

A. The maximum height must be less than 100 cm.

B. The maximum height measured at the top of the Driver's compartment must be less than 1.25 times the maximum track width between the two outermost wheels.

C. The track width must be at least 50 cm, measured between the midpoints where the tyres touch the ground.

D. The wheelbase must be at least 100 cm.

E. The maximum total vehicle width must not exceed 130 cm.

F. The maximum total length must not exceed 350 cm.

G. The maximum vehicle weight, without the Driver is 140 kg.

**Braking**

A. Vehicles must be equipped with two independently activated brakes or braking systems; each system comprising of a single command control (lever(s) working together or foot pedal), command transmission (cables or hoses) and activators (calipers or shoes).

B. One system has to act on all front wheel(s), the other on all rear wheel(s). When braking on two steering wheels at the front, two activators (calipers or shoes) have to be used-one on each wheel, commanded by only one command control. In addition, the right and left brakes must be properly balanced.

C. The rear system must work on each wheel, unless they are connected by a common shaft in which case they can have a single system.

D. It must be possible to activate the two systems at the same time without taking either hand of the steering system. Foot control is recommended.

E. The effectiveness of the breaking systems will be tested during vehicle inspection. The vehicle will be placed on an incline with a 20 percent slope. The brakes will be activated each in turn. Each system alone must keep the vehicle immobile.

F. The use of a hydraulically controlled braking system is highly recommended.

### 2.5 Constraints and Other Considerations

**Driver Position**

For safety reasons, the head-first driving position is prohibited.

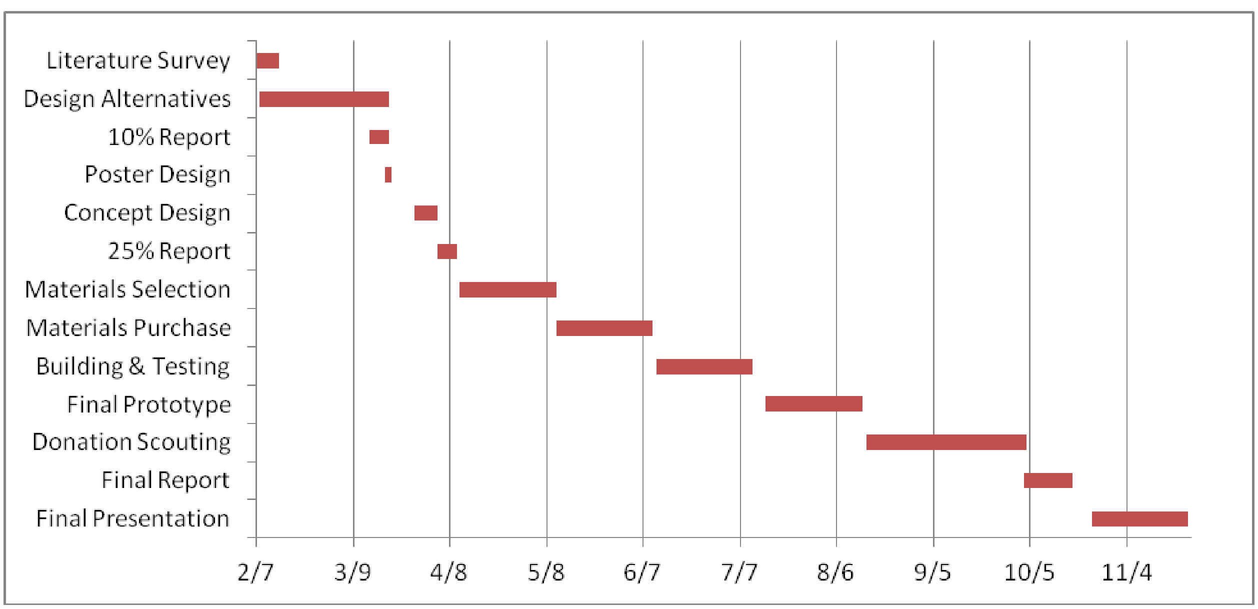
## 3 Project Management

### 3.1 Breakdown of Work into Specific Tasks

The following Table 2 depicts the work tasks of each member. Each member will have their fair share in research, assembly and final report. Individually, Alan was in charge for engine selection and to order materials. Alex responsibilities were competition requirements, body and cockpit design. As for Daniel he will take part in chassis design.

### 3.2 Organization of Work and Timeline (Timeline for Senior Design Organization and Senior Design time frame)

**Table 1: Timeline**



### 3.3 Breakdown of Responsibilities Among Team Members (Indicate Each Member's Major and Support Roles for Each Task)

**Table 2: Tasks and Responsibilities**

| Operations | Alan | Alex | Daniel |
|---|---|---|---|
| Preliminary Reasearch | ■ | ■ | ■ |
| Competition Reqirements | | ■ | |
| Engine Selection | ■ | | |
| Chassis Design | | | ■ |
| Body/Cockpit Design | | ■ | |
| Order Materials | ■ | | |
| Assembly/Testing | ■ | ■ | ■ |
| Final Write Up | ■ | ■ | ■ |

**Table 3: Work Hours**

| Team Member | Actual Hours Spent in Spring 2013 | Expected Hours Summer 2013 | Expected Hours Fall 2013 |
|---|---|---|---|
| Alan | 28 | 40-80 | 80-120 |
| Alex | 26 | 40-80 | 80-120 |
| Daniel | 24 | 40-80 | 80-120 |

## 4 Engineering Design and Analysis

The Shell Eco-marathon prototype can be broken down into several component assemblies. The most complex assembly is the drive train assembly which consists of a gasoline powered engine and clutch/transmission. There will be a one piece internally accessible lightweight body. The cockpit will contain the driver's safety harness and controls for driving the vehicle (Steering, power, braking, turning the engine on/off). Low rolling resistance wheels and high performance bearings/bushings will be used. The vehicle will be tied together by the chassis which will contain a safety bulkhead separating the driver from the engine compartment. All of these components together will produce a safe efficient marathon treading vehicle.

### 4.1 Structural Design

The chassis will support the driver and engine during the operation of the vehicle. It must be lightweight and yet strong. This will be accomplished using 6061-T6 Aluminum tubing. A frame with a considerable strength to weight ratio can be achieved with this tubing. The size of the frame must allow for the vehicle to fit within competition guidelines. It must take into account the top load of the driver, engine, and accessories as well as resist torsion during operation. A safety Bulkhead must be attached to the frame separating the driver from the engine compartment. A roll bar must be of sufficient height and strength to protect the driver. There will also be a sturdy engine mount attached to the frame to ensure reliable operation.

### 4.2 Cost Analysis

**Table 4: Full Cost Analysis**

| Cost Estimation | | | |
|---|---|---|---|
| **Drivetrain Assembly** | **Quantity** | **Cost** | |
| Engine | 1 | $ | 550.00 |
| Mounts (Set) | 1 | $ | 25.00 |
| Throttle Control Lever/Cable | 1 | $ | 35.00 |
| On/Off Switch | 1 | $ | 3.55 |
| Emergency Shut Off Switch | 2 | $ | 7.80 |
| Exhaust Piping (set) | 1 | $ | 31.99 |
| Misc Components | 1 | $ | 75.00 |
| | Subtotal: | $ | 736.14 |

| Chassis Assembly | Quantity | Cost | |
|---|---|---|---|
| Tubing (6ft Lengths) | 6 | $ | 58.17 |
| Wheel Hubs | 2 | $ | 24.99 |
| Fabrication (Contracted Labor) | 1 | $ | 450.00 |
| AL Flat Bar (For Gussets and Such) | 2 | $ | 9.97 |
| Misc Components | 1 | $ | 125.00 |
| | Subtotal: | $ | 868.94 |

| Brakes, Steering, and Wheels | Quantity | Cost |
|---|---|---|
| Wheels | 3 | $ 99.99 |
| Brakes | 2 | $ 44.99 |
| Pedals | 2 | $ 35.99 |
| Linkages (Set) | 1 | $ 21.99 |
| Steering wheel | 1 | $ 29.00 |
| Steering Column | 1 | $ 15.00 |
| Tie Rods | 2 | $ 19.99 |
| Tie Rod Ends | 4 | $ 12.99 |
| Misc Components | 1 | $ 125.00 |
| | Subtotal: | $ 744.86 |

| Cockpit Accessories | Quantity | Cost |
|---|---|---|
| Horn | 1 | $ 5.00 |
| 5 Point Safety Harness | 1 | $ 25.00 |
| Fire Retardant Insulation | 1 | $ 15.10 |
| Seat Padding | 1 | $ 10.95 |
| Misc Components | 1 | $ 75.00 |
| | Subtotal: | $ 131.05 |

| Body Materials | Quantity | Cost |
|---|---|---|
| Urethane Foam Sheets for Mold | 3 | $ 15.97 |
| Wood for Mold | 1 | $ 50.00 |
| Fiberglass Sheeting (9 ft^2) | 21 | $ 5.50 |
| Epoxy and Hardener | 4 | $ 36.00 |
| 0.125" Lexan for Visibility | 4 | $ 4.30 |
| Misc Components | 1 | $ 175.00 |
| | Subtotal: | $ 549.61 |

| Safety Gear | Quantity | Cost |
|---|---|---|
| Gloves (Pair) | 3 | $ 1.49 |
| Safety Glasses (Pair) | 1 | $ 0.89 |
| Earplugs (box) | 1 | $ 2.99 |
| Warning Labels/Signs | 5 | $ 3.99 |
| Class ABC of AB Fire Extinguisher | 2 | $ 19.99 |
| | Subtotal: | $ 68.28 |

| Event Participation | Quantity | Cost |
|---|---|---|
| Round Trip Flights to Houston | 3 | $ 780.00 |
| Hotel (Per Night) | 3 | $ 92.96 |
| Food, Drink, etc (Per Person) | 3 | $ 90.00 |
| Vehicle Transport | 1 | $ 999.00 |
| | Subtotal: | $ 3,887.88 |

| Expected Contributions | Quantity | Donation |
|---|---|---|
| Sponsor 1 | 1 | $ - |
| Sponsor 2 | 1 | $ - |
| Sponsor 3 | 1 | $ - |
| | Subtotal: | $ - |

| | |
|---|---|
| Grand Total | $ 6,986.76 |

## 5 Prototype Construction

### 5.1 Description of Prototype

The 2014 Florida International University Shell eco-marathon vehicle will be the only one of its kind. Stating that since our time and budget is limited; only one vehicle can be made. After testing and discovering any flaws with our design the appropriate actions will be taken onto the designed car made.

### 5.2 Prototype Cost Analysis

The cost for the prototype vehicle will be the same as the cost analysis as stated in 4.2 Cost Analysis since the car will be created just once and fixed appropriately after testing for further efficiency of the vehicle.

## 6 Testing and Evaluation

Once completed the Shell eco-marathon vehicle will be tested on its aerodynamics, weight, and fuel efficiency. Testing for aerodynamic will be provided by Florida International University's "Wall of Wind" where the vehicle will be tested for drag coefficient. For determining the weight of the vehicle, the Shell eco-marathon vehicle will be brought to a truck scale. Lastly a test run on one gallon of fuel will be taken place at a dyno for discovering its maximum miles per gallon. Evaluations of the vehicle will be taken into account and any necessary changes to optimize the vehicle will be taken immediately.

### 6.1 Design of Experiment – Description of Experiments

During the summer months Dynamic Engineering Solutions plans to fabricate/modify the essential component assemblies. During the month of May the team will purchase necessary materials and components. In the following month of June the team will begin assembling and testing individual component systems. During the month of August before the fall semester starts the team hopes to begin full prototype tests. We are currently looking for a suitable track where we can do reasonably long distance trials. With our current projected timeline the team hopes to ensure extra time for fine tuning the vehicle and presenting the necessary information in the final report.

## Conclusion

For the purpose of the project, a very lightweight, low center of gravity and fuel efficient engine would be the best fit for this design experiment. Other considerations were thought of such as driver position and carbon fiber material, however due to budget constrains we believe that we'll be proud of our final decision and model of our Shell-Eco marathon vehicle.

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