EML 4905 Senior Design Project

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REQUIREMENT FOR THE DEGREE OF
BACHELOR OF SCIENCE
IN
MECHANICAL ENGINEERING

Shell Eco-marathon
Final Report

Alan De La Paz
Daniel Duncan
Alejandro Parjus

Advisor: Professor Andres Tremante

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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.

Alan De La Paz	Daniel Duncan	Alejandro Parjus
Team Leader	Team Member	Team Member

Dr. Andres Tremante
Faculty Advisor

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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) Urban Concept 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 Urban Concept 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 cm² (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 Urban Concept 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 tires 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.

2.6 Conceptual Design

For the 2014 model of FIU's Shell Eco-marathon, the 2013 model will be redesigned for simplicity. For some insight of last year model Shell Eco-marathon, FIU participated in the competition however the ergonomics of the vehicle made it very hard to steer and accelerate. Due to theses constrains the driver was unable to control their vehicle and ended up colliding into a wall, demolishing the vehicle. The scraps of last year's model will be used to construct a new easy to use and practical vehicle. The purpose of this new model car is to be able to compete fully in the 2014 competition.

Over inspection of the scraps from the old model steering seem to be very difficult. The steering configuration was a horizontal bar located on the driver's left hand side by their waist. In order to drive straight the driver had to maintain the bar at a level of equilibrium, if the driver dropped the bar the vehicle would veer right, and if the driver pulled to high on the bar the vehicle would veer left. This complex steering would be changed for the 2014 model with a simple bike steering and steering column.

Another aspect the old model vehicle had was acceleration issues. On the right hand side of the driver by their waist was the throttle. However the throttle had to me manipulated to conform to the car in an unethical manner. For the new model the throttle would be placed on the steering much like a scooter or a motorcycle. Therefore the steering would be much like a bicycle with an actual bicycle handlebar and the throttle on the right hand side.

One of the major problems the past model had was the practicality of the vehicle. The frame design was kept to only have a very thin and short person to maneuver the vehicle. This idea is great for lightweight design however realistically to find a person that can fit into the frame would be hectic. For some insight the driver had to have shoulders no longer than 15 inches long, from tip to tip. To work around this frame conditions, two pillars of the frame must be removed in order for an average person (5'7" 180 pounds) to be fit inside the cockpit of the vehicle.

3 Analytical Analysis

Since the new 2014 competition vehicle will be a remodel of the 2013 vehicle, a CAD drawing of the old model was made in order to derivative a new body shape for the designs. The CAD software used was SolidWorks 2013 since it is supplied by the university. Below in figure 2 shows the current state of the 2013 model. The actual frame design isn't made, this drawing of the vehicle is to gather dimensional information for a monocoque body design. The actual frame is made up of carbon fiber tubing that are one inch in diameter. Analytical studies are being presented to this drawing daily for optimal body design and simulations are being taken place in order to determine the best fit body.

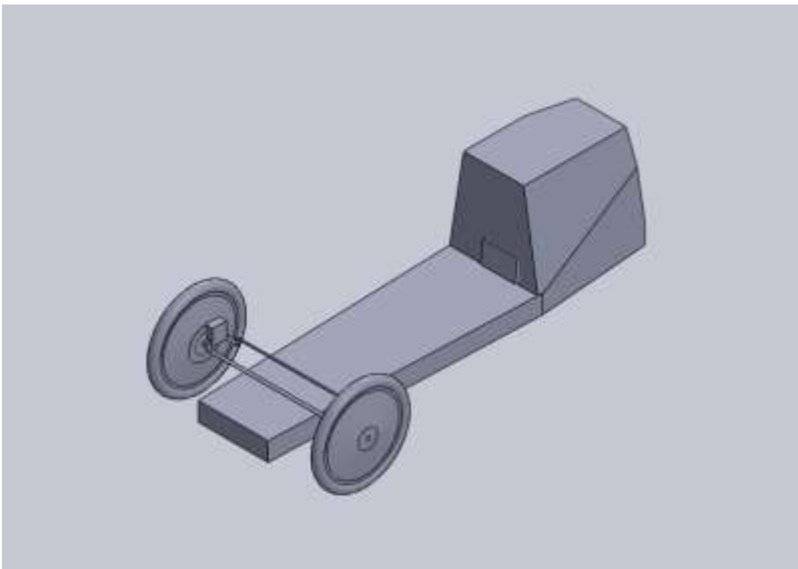


Figure 2: Frame Design

4 Major Components

The redesign of the old vehicle leaves a lot of work for the new model. The largest component of the vehicle that needs to be changed immediately is the ergonomics. Steering would be changed into a handlebar configuration much like a motorcycle. The steering would react like a bicycle and the throttle would be placed on the right hand side of the handlebars. As for the front wheels, the wheels must be placed upright at a 90 degree angle perpendicular to the ground. Last year vehicle had the front tires at a slight angle which did not utilize the tires to their maximum potential. The tire would be placed perpendicular to the ground so that the apex of the tire touches the surface of the ground. With the front tires placed as needed, the steering column can be manufactured.

The engine itself is a four stroke Vespa Scooter engine. This engine style has the transmission fused together with the engine itself so there is no changing the transmission. Besides that the engine is equipped with a scooter tire that must be changed into a bicycle tire for lightweight design and a smaller surface area that touches the pavement. However the tire and rim for the scooter is a two-in-one tire. This tire is a drum brake and tire at the same time, to change this tire into a bicycle tire will cause a lot of designing and manufacturing in order to convert. Lastly the engine is driven by a belt which is less efficient than a chain link belt. The transformation needs to be changed in order to obtain maximum fuel efficiency.

The last major component of the 2014 vehicle design would be the monocoque body design. This body would need to be simple design that allows easy access for entering and exiting the vehicle. An aerodynamic shape would be consider in the designing process for that the vehicle can easily slice through the air with very little resistance and a low drag coefficient. With an aerodynamic body shape the vehicle would then reach its maximum potential of fuel efficiency.

5 Structural Design

Using the 2013 vehicle model as a template, the structural design would reflect much of last year's design. The carbon fiber base frame will still be used yet modified for a more practical and realistic driving experience. Then the steering would get upgraded to a more sensible and normal usage. 2014 model will have a steering column for easy driving much like a scooter or a motorcycle.

5.1 Steering

Theory

There are many factors and theories to take into consideration when design a vehicle's steering system. Wheel toe, castor, and camber must be aligned for the specific application. If a vehicle is designed in such a way that when the vehicle makes a turn the two front wheels remain parallel with respect to each other , the end result will be that one the wheels will turn around different radius centers. This results in one wheel turning smoothly around the curve while the other is forced to slide radially as it turns. This causes unnecessary wear and loss of kinetic energy through friction. One widely applied solution to this design problem is known as Ackermann's steering geometry.

Ackermann's steering geometry requires that the two wheels turning radii be concentric with respect to each other. The center of the radii must be then be aligned on a transverse line that passes through the rear axle. When this geometric configuration is achieved the front wheels will turn smoothly with minimum wheel slide. This geometry does not necessarily apply to all steering systems such as high speed sports cars, but is highly effective at mid to lower speed maneuvers. Ackermann's geometry is a useful tool in the design of a vehicles steering system.

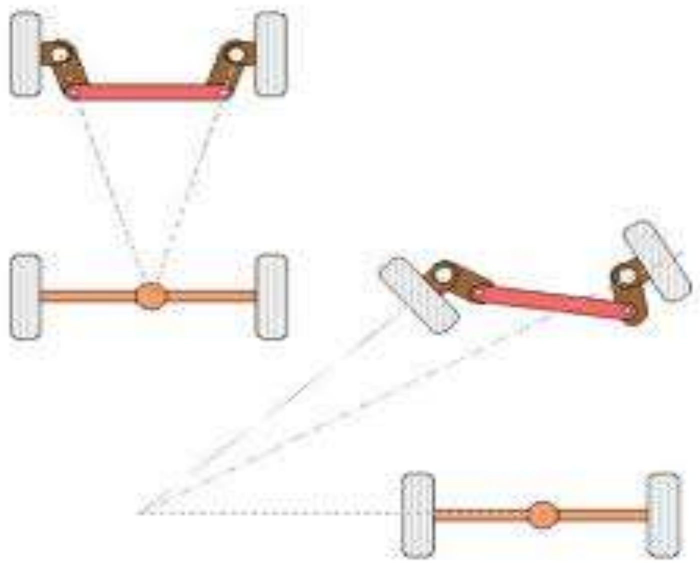


Figure 3: Ackermann's geometry maintains turning radii with respect to the rear axle

Generally, automotive vehicles use either steering wheels or handlebars to steer the vehicle. These are preferred methods because the control mechanism must be turned in the direction that the vehicle is desired to turn. This allows the driver to turn the vehicle more instinctively with minimal extra thought to handle the turn. It is for these reasons that these control devices are so widely used.

Application

The aforementioned theories and geometrical designs will be applied to Team Dynamic Engineering Solutions' senior design project. The entire front end steering geometry, steering control mechanism, and operator cabin are being redesigned for the 2014 FIU Shell Eco-marathon cart. The Ackermann geometry will be applied in conjunction with specially designed wheel pivots to allow for proper wheel camber and castor. Another area of focus will be centered on integrating the steering, braking, and throttle controls into an effective and easy to use system. All of these improvements will be implemented through specialized designs that are based on these fundamental design theories.

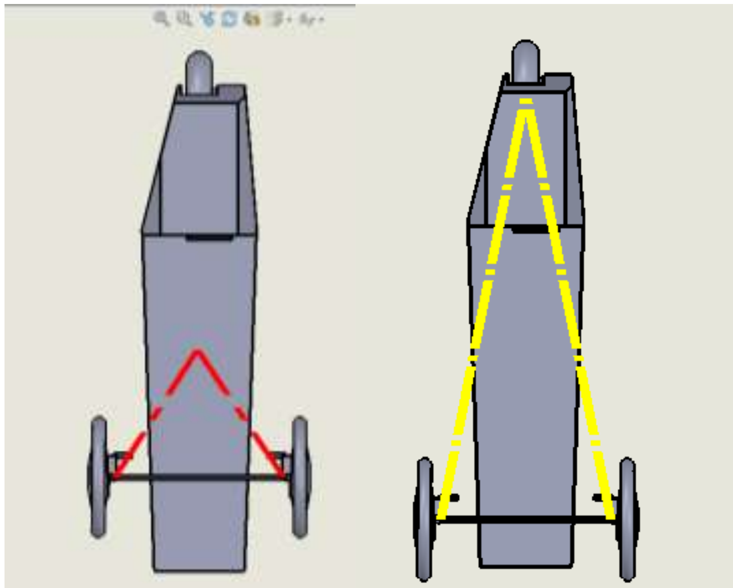


Figure 4: Previous steering geometry (Left). Proposed Ackermann steering geometry design (Right)

Special new wheel pivots have been designed to modify the wheel's camber angle. The wheels are mounted on hubs with approximately 12 degrees of negative camber. The previous design used aluminum pivots that positioned the wheels at the full 12 degree negative camber. While negative camber increases corner handling, it reduces straight line performance such as acceleration and braking. When considering the relatively low speed of 15 mph that is required for the eco-marathon track, 12 degrees negative camber is excessive. The new pivots will be offset at an angle of 10 degrees to give the cart approximately 2 degree negative camber. This wheel alignment configuration is more properly suited for the given design criteria of the cart and will result in a better performance overall.

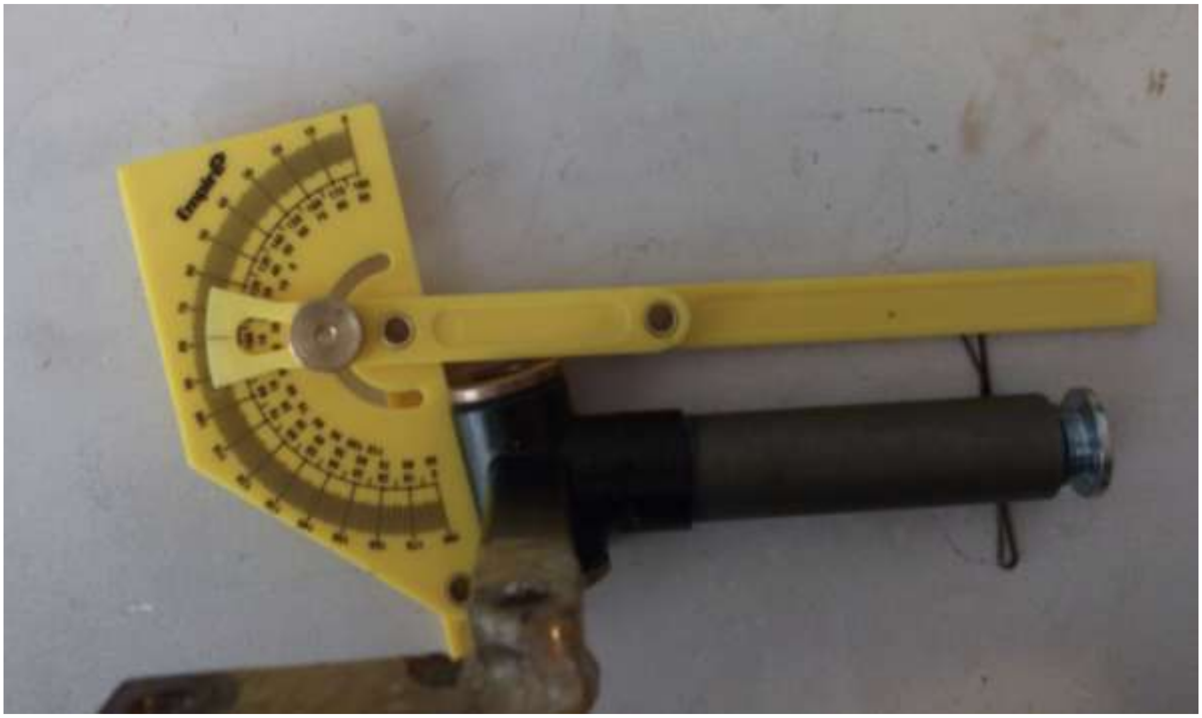


Figure 5: The 12 degree offset hub that mounts the Michelin 44-406 20 inch tire and rim

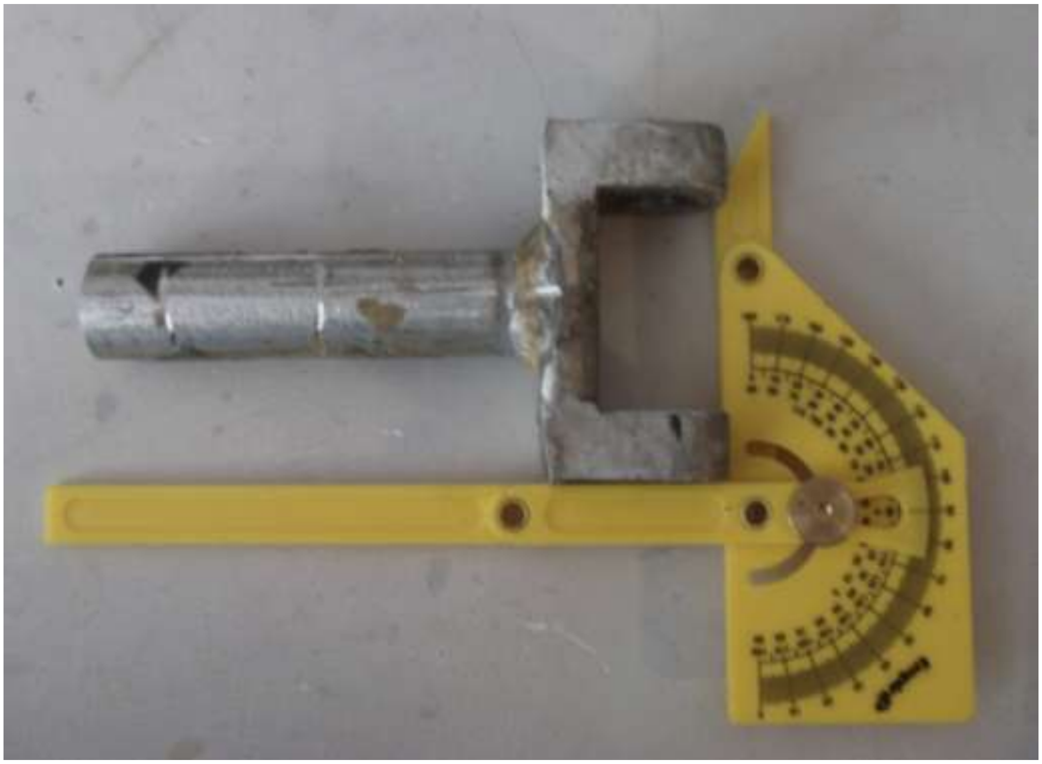


Figure 6: The old 0 degree offset eco-marathon cart pivot that received the wheel hub

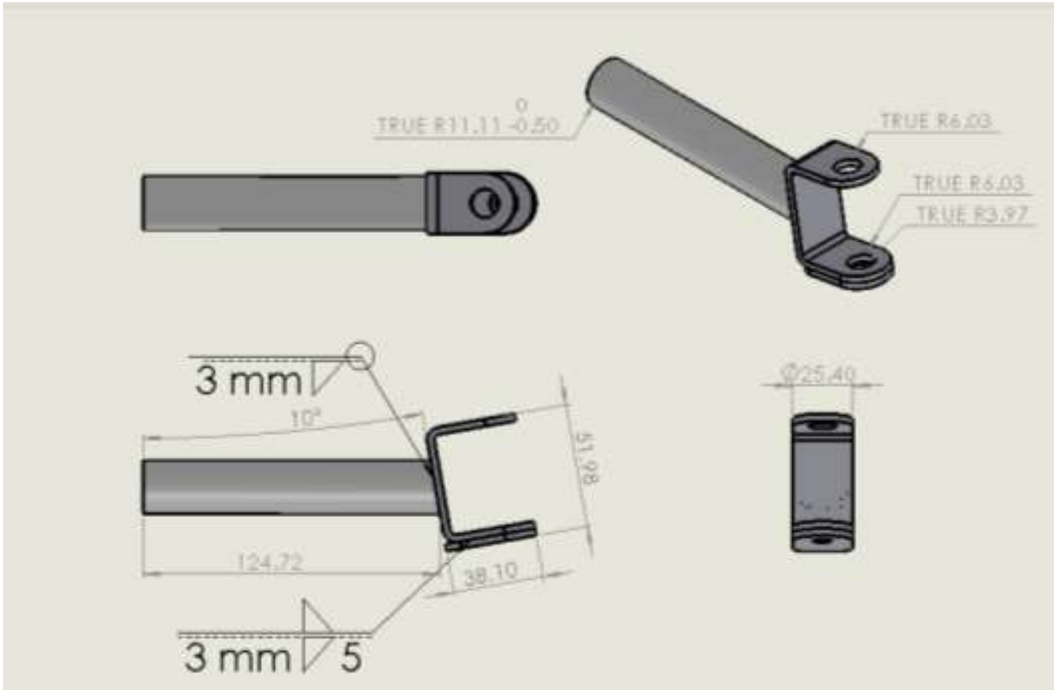


Figure 7: The new 10 degree offset pivot that is currently being fabricated

The steering setup of the previous design needed to be redesigned for a more ergonomic scheme. The old system comprised of a longitudinal mounted steering lever. The steering was actuated by either pulling or pushing the lever forwards or backwards. This was due to the fact that the power train for the cart was adapted from a scooter. There were also unexpected geometric constraints from the frame and body that led to this design. This irregular steering concept will be replaced with a more intuitive design.

Figure 8: The shaft with internal wires facing down is the pivot for the steering lever. This mechanism will be adapted to a steering wheel

A new highly adaptive design can integrate the current steering and braking components and actualize an efficient steering wheel setup. The cart utilizes hand lever brakes that are similar in design and construction to bicycles brake system. These components in conjunction with resourceful new redesigns will provide a safe and efficient drive control scheme. A main steering wheel will be connected to the steering system. This steering wheel will be the base to which the throttle control mechanism and brake handles attach. This will provide a centralized control scheme that is not only ergonomic and intuitive, but also efficient and compact as well.

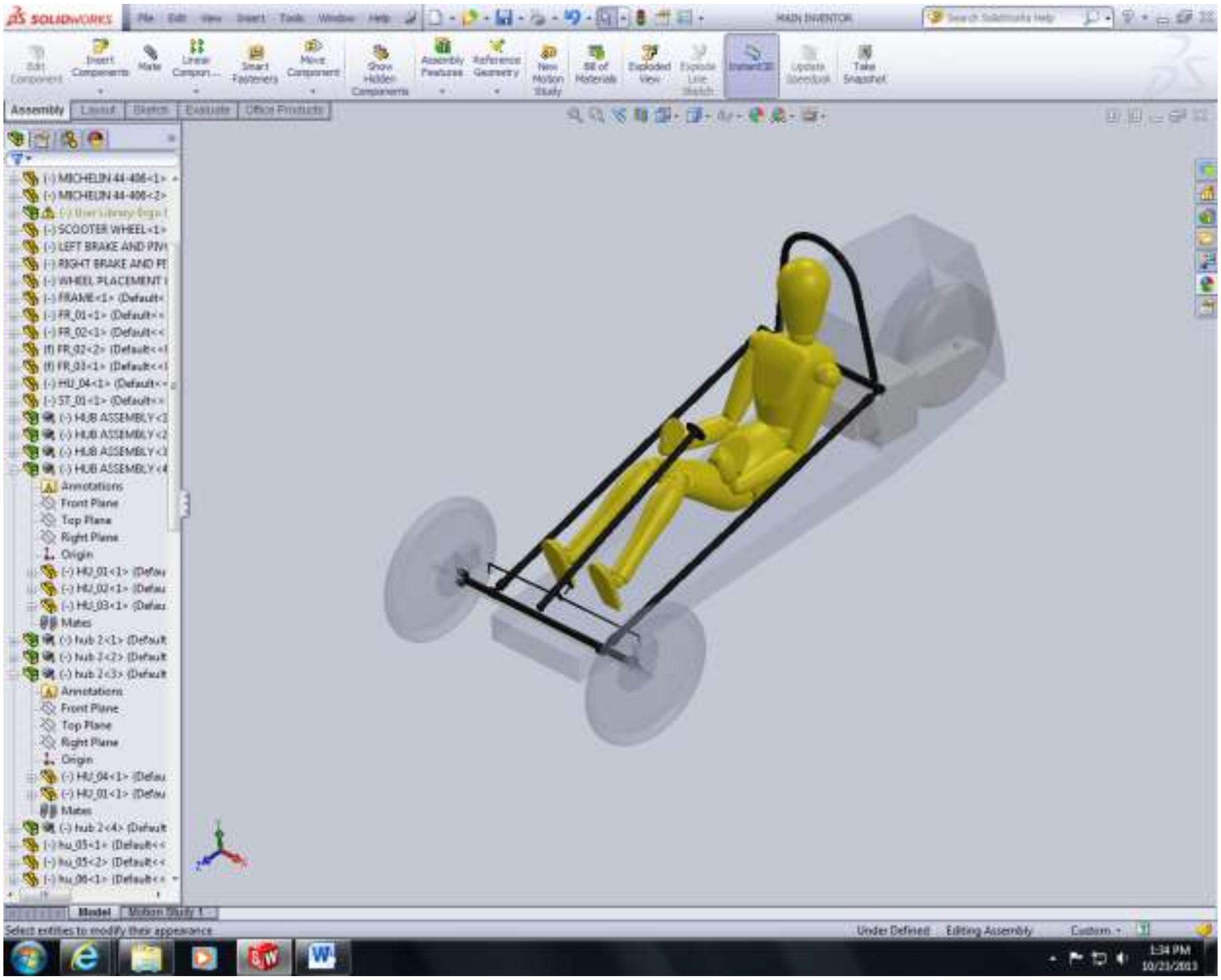


Figure 9: Preliminary front end redesign components and driver cabin enlargement

The eco-marathon driver's cabin needs to be resized for the current team. It was originally designed for a small framed lightweight female driver. This year the new eco-marathon is comprised of larger framed male members. To accomplish our goal of enlarging the cabin, we had to trim out the previous diagonal tube supports and build a new larger frame accommodate our group driver. The new design calls for a horizontally mounted bar to be attached at the rear upper portion of the cabin and to extend past the operators shoulders. In between this horizontal support and the new front axle, diagonal support members can be installed to create a structure to support the loads on the frame. The extension of the frame around the driver will deliver the necessary space for comfortable operation.

With the expansion of the driver cabin several safety features will have to be modified. The driver position is being changed from a nearly supine position to a seated position. This will require the addition of a roll bar to protect the driver in the event of an accident. The firewall between the driver and the engine compartment will have to be increase into the roll bar area. The fire extinguisher will be relocated from the foot of the driver to a more accessible location in the side of the driver cabin. These features will meet the safety requirements of the event and will be efficiently distributed in the new body design.

Team Dynamic Engineering Solutions plans on testing at least 3 body design variants before fabricating the new exterior body. As of date only one such body has been modeled and tested. We are waiting for the steering and driver cabin redesign to be assembled and measured before fully finalizing the body design. The first such preliminary design encapsulates the driver and the engine compartment into a sleek aviation styled body.

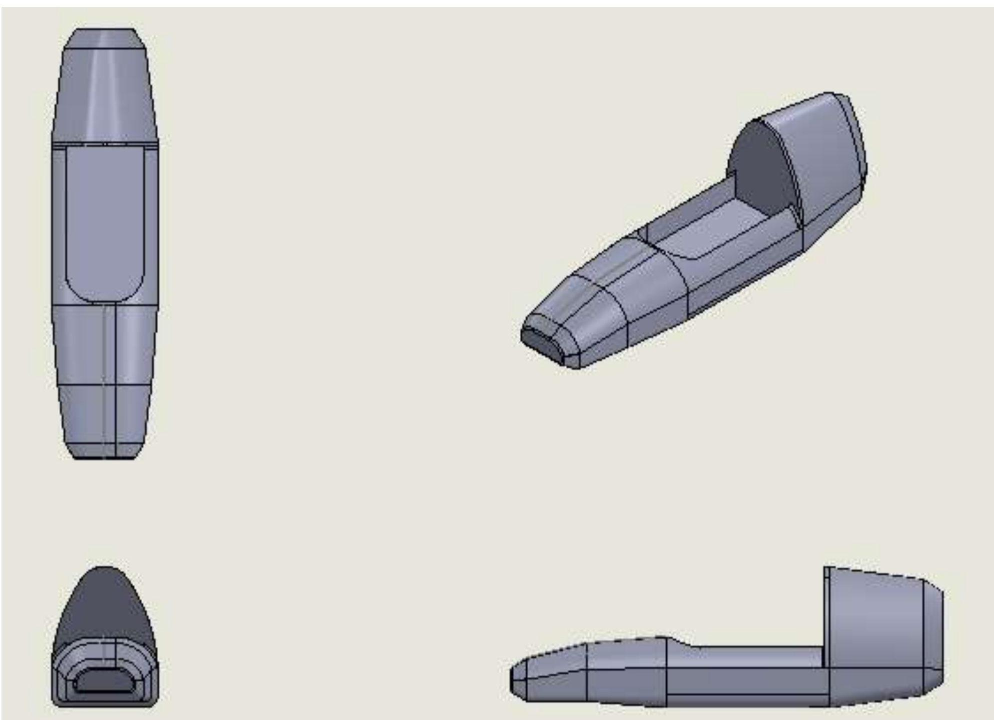


Figure 10: Preliminary design concept alternative 1

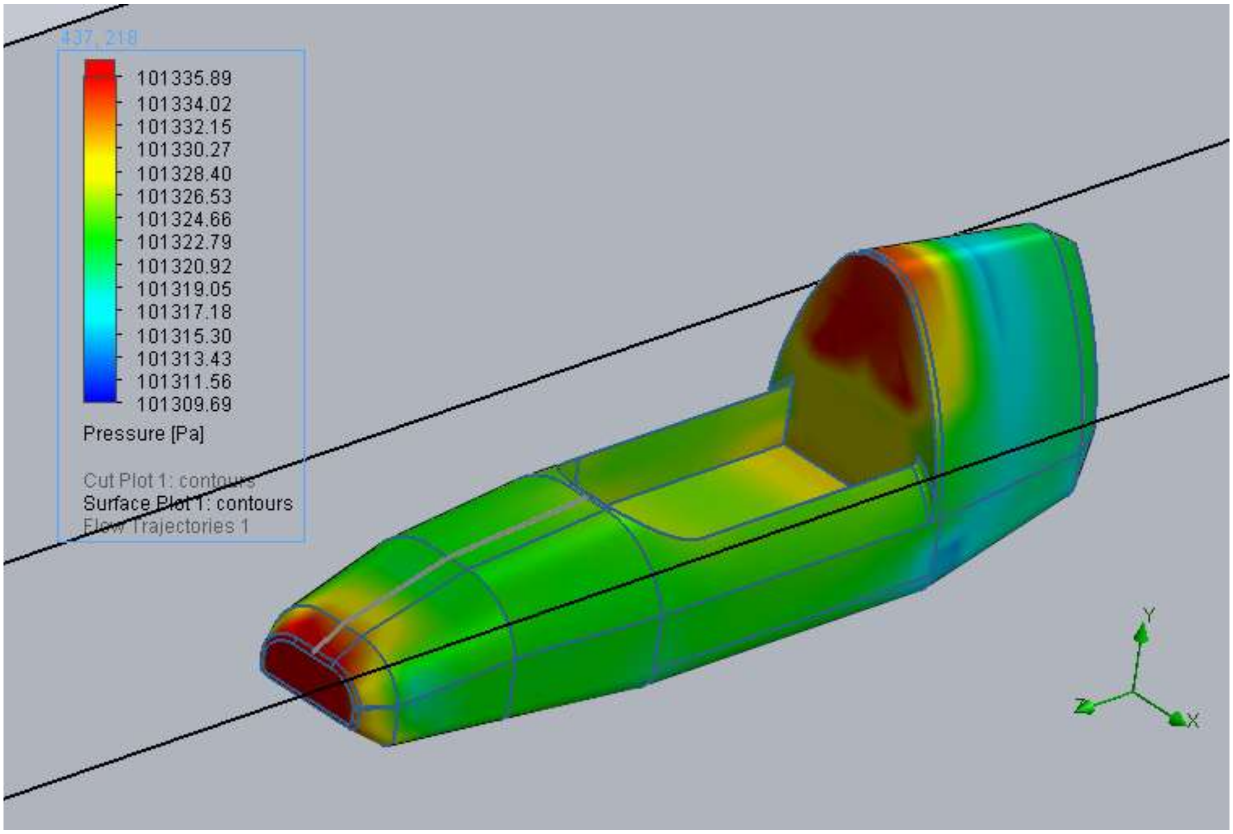


Figure 11: Pressure distribution surface of the preliminary design concept alternative at 15 MPH (6.7056 M/S)

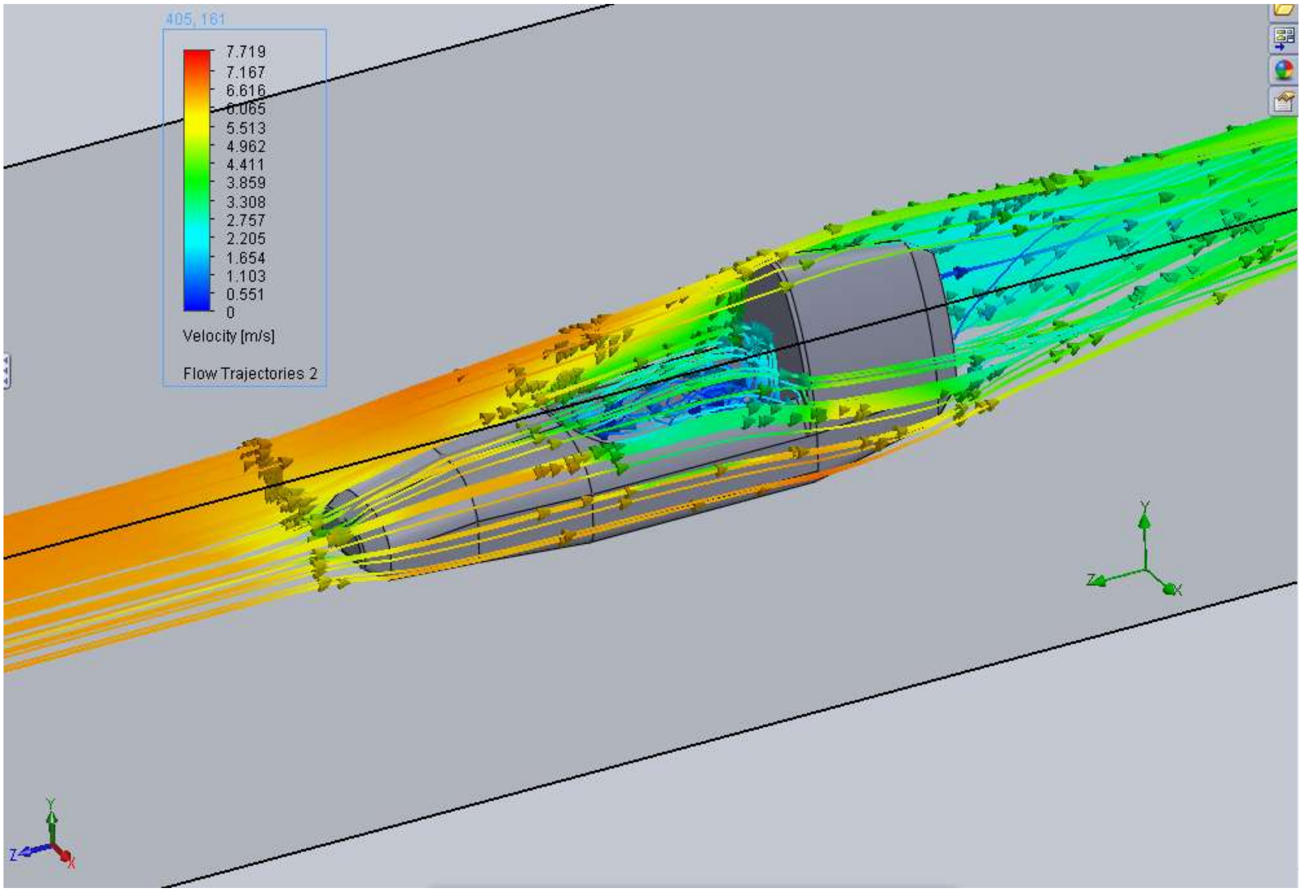


Figure 12: Airflow across the preliminary design concept alternative at 15 MPH (6.7056 M/S)

Extensive computation fluid dynamics (CFD) testing will be applied to all design variants before the final decision will be made. The preliminary CFD results for the first design variant give us some insight on which section needs the most focus. Notice the bubble of air pressure encompassing the engine compartment and the nose of the vehicle. These areas produce the largest change in air velocity and have the highest surface pressure. The nose needs to be stream line to a point and the body needs to be reduced around the engine compartment where possible. These design modifications based on CFD will help streamline the vehicle and make it more efficient.

All of the aforementioned design modifications except the body are expected to be full ready and assembled within the first two weeks of November. Immediately after this final body design will be sent for fabrication. While the body is in production the team will be busy road testing the vehicle to get baseline fuel efficiencies and to evaluate all of the design modifications displayed here. The last modification will be the body installation. By the end of November team Dynamic Engineering Solutions expects the 2014 FIU eco-marathon cart to be fully functional and operating at maximum efficiency.

5.2 Body Design

The body design for the 2014 Shell Cco-marathon vehicle needed to fit upon the 2013 model frame design. The preliminary design of the body was to create a lightweight yet aerodynamic design in order to be lightweight and fuel-efficient. At first the major constrain of the design is spending fees. With a tight budget, a simple yet useful design was then implemented. Over all FIU’s 2014 Shell Eco-marathon team is looking to compete more than win first place. A simple body design that does the job and is able to compete with other schools around the nation is what our team is looking forward to.

In order to design a body, the frame that is already in use must be created in CAD and build around those existing parameters. After taking the dimensions the below figure illustrates the frame being used for this vehicle.

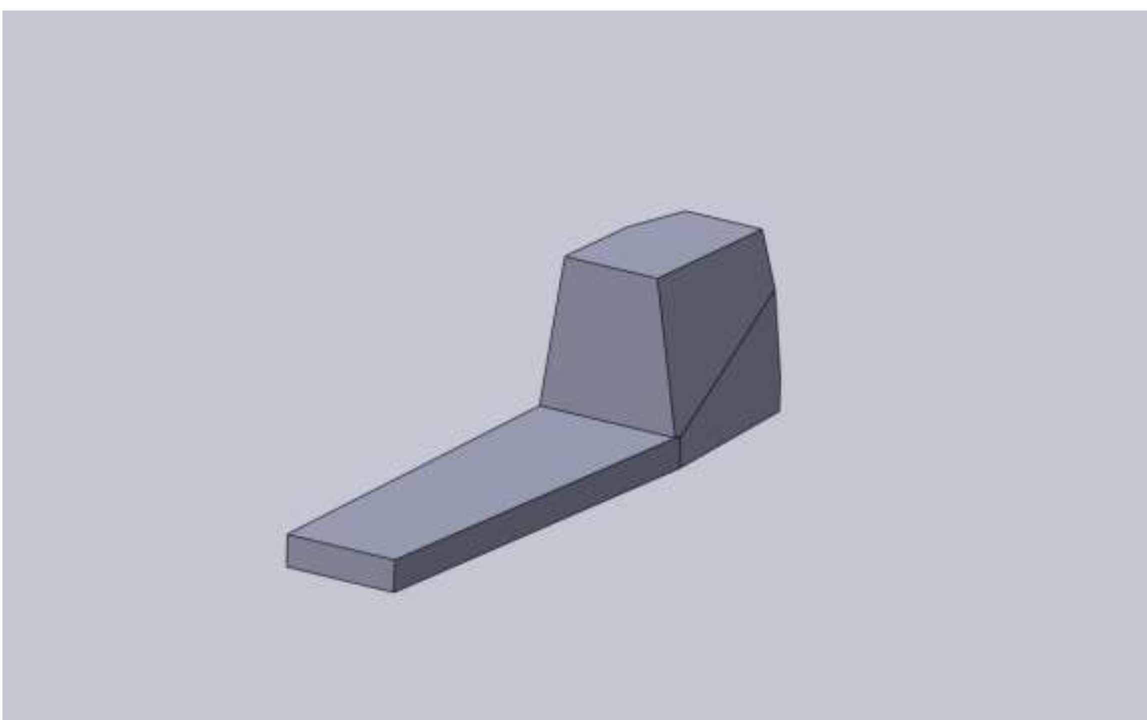


Figure 13: CAD model of frame design

The rough CAD model above only shows major componets of the frame. The frame itself is made out of carbon fiber tubes, however for the sake of designing the body, we only need the dimensions. After reviewing many past Shell Eco-marathon vehicles a simple yet easy to make vehicle was decided. The easy to make model was implimated strickly for cheaper building price.

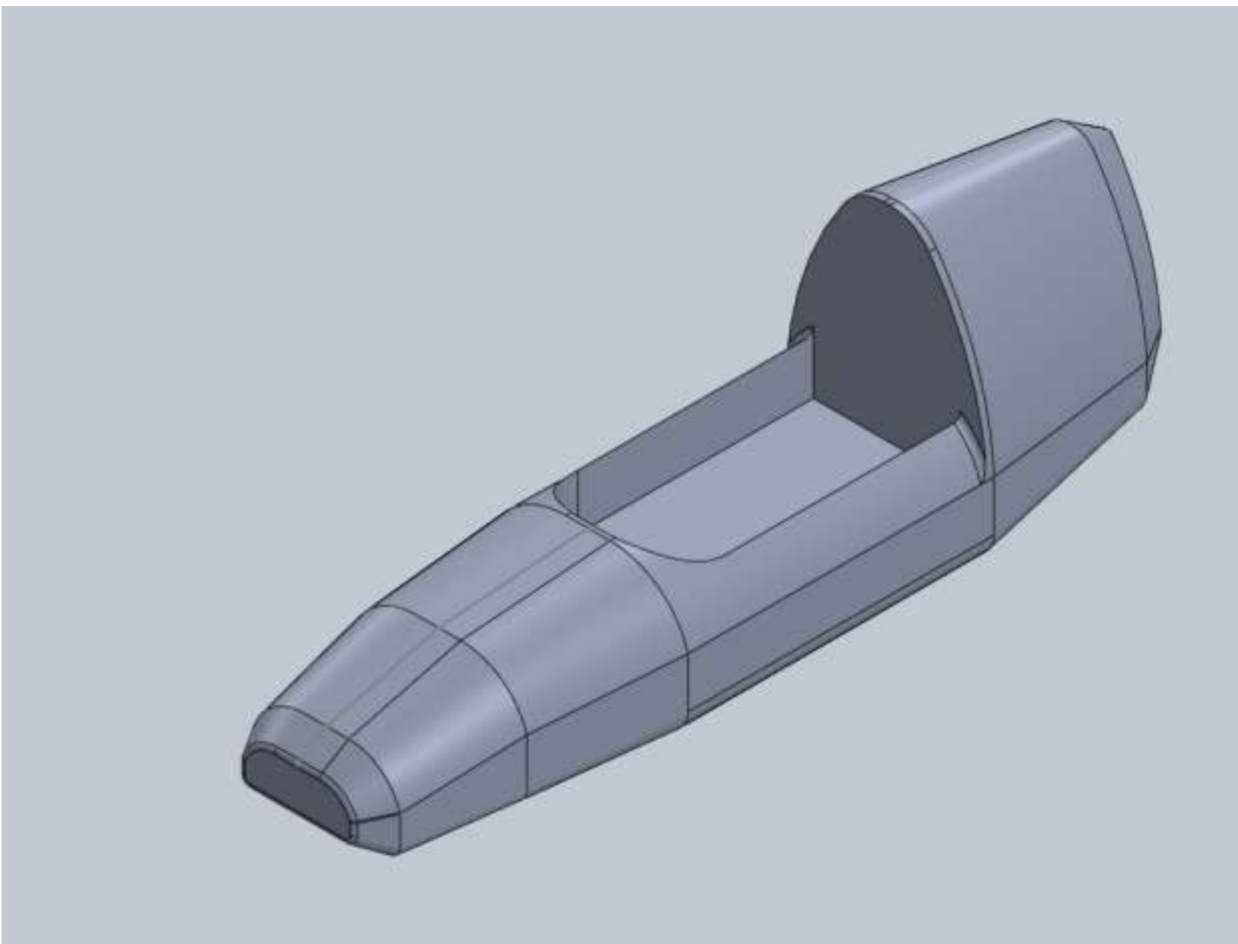


Figure 14: Preliminary Body Design

Figure 14 shows our first design of a body for the 2013 frame design. After sending out this design to companies for pricing, we had to remove some material in order for a price change and simplicity of manufracturing. After a redesign the body was now in condition to be created in a easy fastion for the foam cutting company. A foam design is first created of the model in order to apply carbon fiber and fiberglass cloth upon the foam. Expoy resin is then applied and another layer fiber cloth is applied, this process is repeated again for a third time createing a strong yet lightweight shell of the foam body.

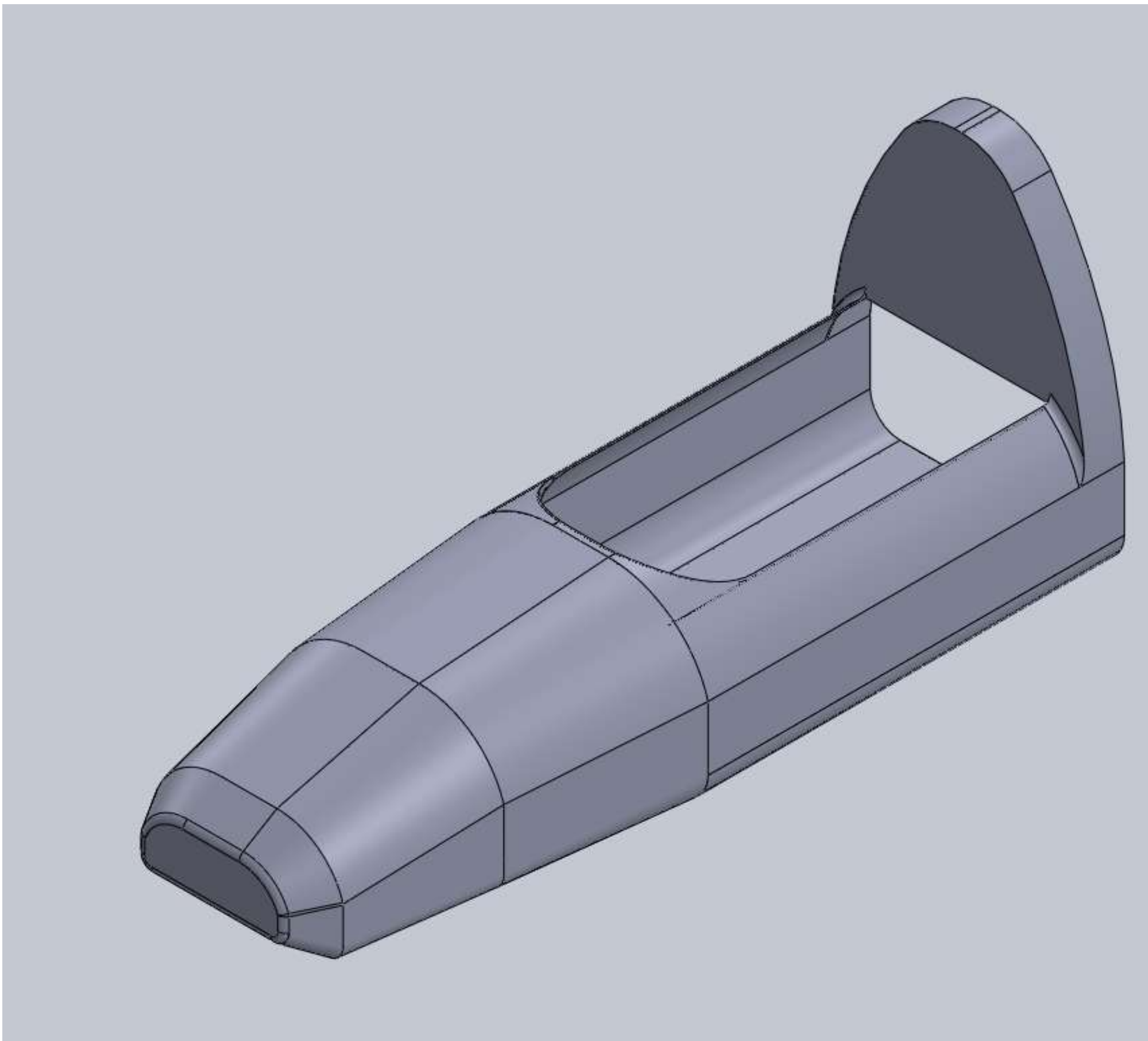


Figure 15: Final Body Design

After revisions, the final body design in Figure 15 was created so that less material would be used in manufacturing. In the final prototype, the engine bay is open allowing airflow to circulate all around the motor.

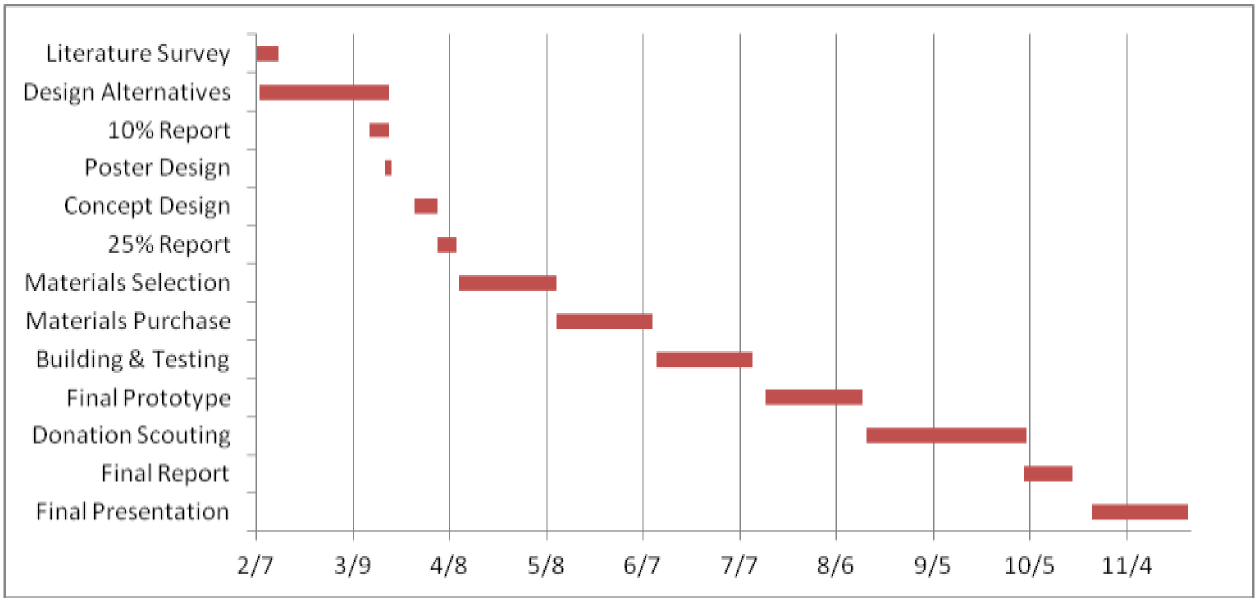
6 Project Management

6.1 Breakdown of Work into Specific Tasks

The following Table 2 depicts the work tasks of each member. Each member will had 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.

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

Table 1: Timeline



6.3 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

7 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.

7.1 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.

7.2 Preliminary 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

8 Preliminary Construction

8.1 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 was made. After testing and discovering, any flaws with our design the appropriate actions will be taken onto the designed car made.

8.2 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.

8.3 Actual Cost Analysis

Many cost alternatives were implemented for this build. At first the team though to purchase the body from a company that would build the prototype, after a few cost estimations the team decided to build the body themselves. The cost for an outside company to create the body was about $10000 to $15000. Since the budget for the team was not that high a different alternative was then advised. Creating the body themselves would be cost efficient yet more time consuming. In order to create a carbon fiber body the team needed a foam cut out of their body. With this foam cut out sheets of carbon fiber can be applied onto the foam and epoxy resin to help glue to sheets in place and take its form from the foam cut out. After shopping around for foaming companies, Florida Hotwire technicians said they would do the foam for $616.00 and can supply fiberglass and resin. Since the team used carbon fiber for its high strength and lightweight abilities, a different company was then used to supply materials.

Carbon fiber sheets where purchased through US Composites, a local vendor of multiple quality carbon fiber weaves. After many considerations of different type of weaves, the 19.7oz 2x2 weave was chosen because of its heavy duty weave and high strength structure. A high strength was needed because the amount of weight applied to the carbon fiber. The total price of the sheets came out to be $750 that included the carbon fiber resin.

In total, the team spent $1366 on this project covering over the body design and steering.

9 Construction

Once the body shape foam cut was completed, the foam body was taken to the machine shop at Florida International University. With close inspection, impurities of the foam body were sanded to an even finish so that a smooth surface can be attained for the application of carbon fiber sheets.

Figure 16: Foam body cutout

The above figure depicts the actual foam cut of the final body design with fine sanded smoothed out edges.

After the carbon fiber was purchased, the process of applying the sheets of carbon fiber was to begin. A cross-stitch of the carbon fiber is shown below in Figure 17.

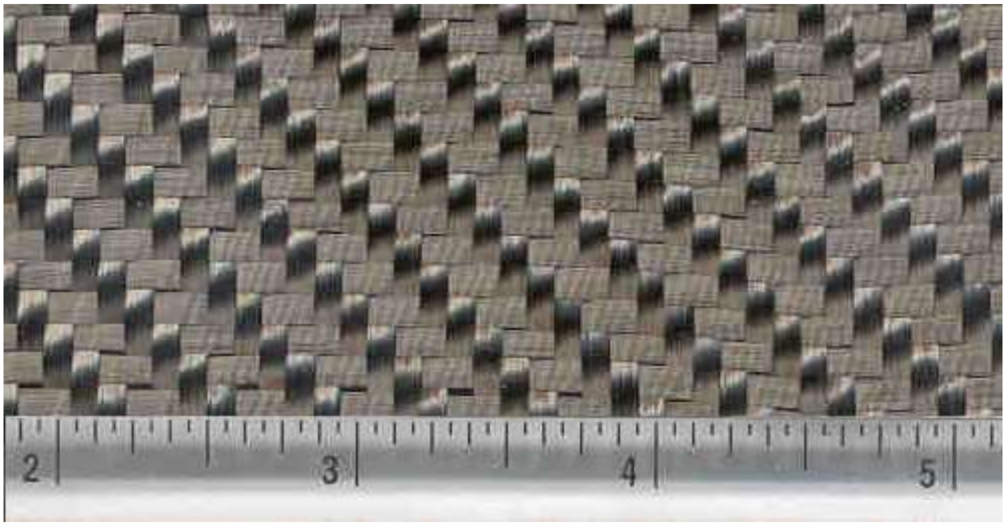


Figure 17 19.7 oz '1st Quality' 2x2 Twill Weave Carbon Fiber

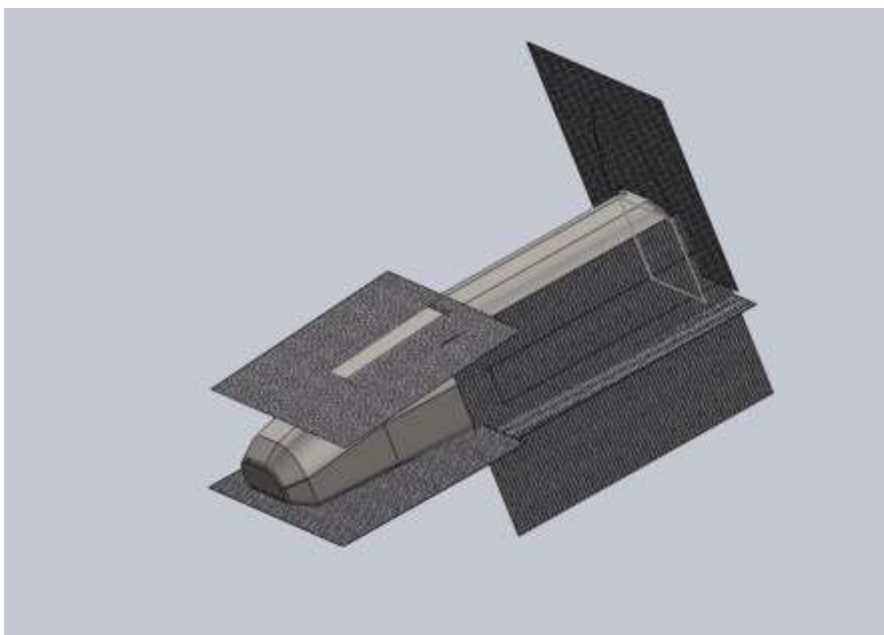


Figure 18: Carbon fiber sheets

Following initial rough estimates of how much carbon fiber would be necessary, calculations revealed that the body needs five 36” x 50” sheets to cover the body one time around. Since the body needs to be strong and sturdy enough to support weight and other components, the carbon fiber will be overlapped two more times for a total of three layers of carbon fiber. Figure 18 above depicts how the number of sheets were determined.

The final construction task for the build involved placing the roll cage and steering column. MWL Engineering provided the tube piping for the roll cage and steering, free of charge. With these components then in place, the design and building process of this project was now completed.

10 Testing and Evaluation

Once completed, the Shell Eco-marathon vehicle will be tested for aerodynamics, weight, and fuel efficiency. Testing for aerodynamics 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, a truck scale will be used with the Shell Eco-marathon vehicle. Lastly, a test run with one gallon of fuel on a dynamometer will be used to determine the 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.

10.1 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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