**FAMU-FSU College of Engineering
Department of Electrical and Computer Engineering**

**PROPOSAL**

**EEL4911C – ECE Senior Design Project I**

Project title: **Formula Hybrid Car 2011**

Team #: 3

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# Project Executive Summary

The Formula Hybrid is an annual international collegiate competition striving to build a formula style, gas-electric hybrid vehicle. This year’s competition takes place in Louden, NH on May 1st, 2011 and is sponsored by IEEE, SAE, and many other corporate entities. The competition consists of a static portion, which includes design judging and presentations, and a dynamic portion, which includes acceleration, autocross, and an endurance race.The FAMU-FSU College of engineering has decided to continue the construction of the car and compete in this event as a part of its Renewable Energy program. The FAMU-FSU College of Engineering is eager to earn international recognition as a school striving to progressively move towards an environmentally friendly society.

Besides this, this formula hybrid vehicle won 1st place in the Hybrid-In Progress Competition last year in New Hampshire of May 2010. The students on this project this year are working diligently to continue the success of the project and win the 2011 competition. The students working on this project are a combination of computer, electrical and mechanical engineering students. The combination of these two engineering fields provides an exceptional learning experience and prepares students for actual industry work.

In addition, the project’s main objectives are to increase fuel efficiency, the performance of the vehicle and the innovation of the drive-train configuration. In order to achieve the objectives mentioned earlier, the following goals will be fulfilled: the integration of the internal combustion engine, the coupling between the internal combustion engine and the electric motor, the continuation of the battery management system, the redesigning of the differential, braking system, body and shell of the formula vehicle.

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# Introduction

## Acknowledgements

The 2011 Formula Hybrid Car team would like to thank Dr. Bruce Harvey and the team members of the 2010 Formula Hybrid Vehicle Team from the FAMU-FSU College of Engineering for their direction and general advising with regards to the vehicle design. Team 5 would also like to officially acknowledge Lei Wang and Xiaohu Liu for their research and guidance in the determination of the drive-train configuration for the vehicle the first year.The team would also like to thank Dr. Chris S. Edrington and Dr. Chiang Shih for their assistance in the fundraising and mentoring of the project. A special gratitude would also like to be extended towards the SASE program at the Florida State University for their assistance in developing a sponsorship plan for Student Government Association. The team has also received tremendous fabrication support and advice from Jeremy Phillips and John Rushing from the car shop and would therefore like to show their immense appreciation to them. In addition, the team of students would like to express their sense of gratitude to the following potential sponsors for their donations and support: Dr. Cartes, IESES, Student Government Association andthe FAMU Foundation. Without all these potential sponsors, the project will be unable to bypass its success!

## Problem Statement

The 2011 FAMU-FSU Formula Hybrid Car Team believes in reducing, reusing and recycling. More so, the “GO GREEN” initiative is what is driving the team to continue the structure of a full hybrid-electric vehicle that will abide by the 2011 SAE/Dartmouth Formula Hybrid Competition rules and guidelines.This project consists of one computer engineering student, two electrical engineering students and three mechanical engineering students. The team of students will engage in the project to design and implement a fuel efficient hybrid vehicle to serve three main objectives such as the following: the reduction of fuel consumption, the improvement of performance on the vehicle and the innovation of the drive-train within the vehicle.

The SAE Dartmouth 2011 competition will consist of three main tests the vehicle will need to perform exceptionally well in. The three main events of the competition will involve the acceleration, autocross and endurance examinations. The previous year’s main challenge was the constructing of the hybrid-in progress vehicle. On the other hand, this year the team of students will be emphasizing the incorporation of the internal combustion engine along with the electric motor to make the vehicle a “full-hybrid car” and maximize the performance within the three main events mentioned previously. One of the main challenges of the competition will be the endurance event since the vehicles will begin by having fully charged their accumulators. Subsequently, the group of students will utilize the Toyota Prius design for the hybrid vehicle which will lead to an intensive analysis of all aspects of the accumulator. In addition, another challenge the team endeavored last year was the uneven charging of batteries within the vehicle. Furthermore, the second main goal of the team is to implement the Battery Management System that will manage the rechargeablility of the battery pack by surveying, protecting and balancing its state. Since it is essential that the end product be battery powered, the team is planning on using the Li-Ion Battery Management System. This BMS includes one of the most attractive features being the balancing of charges throughout the dissipation of excessive energy in most of the charged cells. Additionally, the suspension, body, shell and calipers within the brakes will be redesigned using tools such as Pro-ENGINEER and COMSOL.

## Operating Environment

The operation environment for the Formula Hybrid car will be a flat racetrack or drag strip. The vehicle must and will be operable in a wide variety of climate conditions such as cold, hot, wet, dry, and dusty environments. The vehicle will not be driven off the road at any point. More so the vehicle must be able to operate under high-g turns to maintain the safety of the driver and vehicle integrity. Although in regards to the driver’s safety, one of the vehicle’s desired capabilities will involve the speed, rpm sensors and dials being incorporated into the formula vehicle. Since one control operator will govern the Internal Combustion Engine and Electric Motor, controls for ignition and emergency shutdown will also be incorporated into it. Additionally, the formula vehicle is not in danger of being dropped or thrown, however there is the risk of crashing the vehicle. This danger can lead to the puncturing of the batteries or gas tank and cause a serious hazard but the BMS will detect any abnormal conditions and set a fault accordingly.

## Intended Use(s) and Intended User(s)

The intended end user(s) of this product will be two design team members who will perform as the drivers of the vehicle. Conversely, other team members will pilot the testing of the car. In accordance to the rules and regulations of the SAE rulebook, the vehicle must be designed to fit the largest 5th percentile of men and the smallest 5th percentile of women. The driver must fit the size constraints as set forth by 2010 Formula Hybrid Rules 3.3.4.1, have a validdriver’s license, and motor skills prompt enough to navigate the flat track. The driver’s motor ability level will be measured by the team, although there is not an education requirement for the driver. Other user(s) of the vehicle may vary from the design judges in the actual competition and any potential or present sponsors.

The end uses for this project are to compete in two static events and three dynamic events at the 2011 Formula Hybrid International Competition. The static events include a design inspection and team presentation. The dynamic events consist of a drag race (75m in ten seconds or less), autocross, and an endurance race as mentioned earlier. This vehicle will also be utilized by the design team to stimulate interest in students for potential support and sponsoring in the SASE organization and other potential sponsoring opportunities.

## Assumptions and Limitations

Assumptions: The maximum number of operators will be one. The car will be painted blue and white to in order to represent the colors of the FAMU-FSU College of Engineering. The entire team will travel to Loudon, New Hampshire in May 2011 for the competition. Hybrid team sponsors will be displayed on the vehicle, apparel, banners, and website.

Limitations: The total project needs to be completed before May, 2011 and the total cost must fit within the final agreed budget. The total weight of the Formula Hybrid Vehicle should not exceed 700lbs. The operator must fit within the 95th percentile of men and 5th percentile of women. The battery bank should deliver a minimum of 72 V to the electric motor controller. The drive train system must fit within the dimensions of the chassis. The motor controller cannot attempt to draw more power than it is provided by the battery bank. The electric motor and Internal Combustion Engine must be in synch when both are in operation.

## Expected End Product and Other Deliverables

The expected end product for this project will be a Full Hybrid vehicle, with a parallel drive train configuration. This vehicle will be able to accelerate 75 meters in less than 10 seconds, and complete at 22 km within a reasonable speed to compete against the rest of the competitors.

This package will also include an external charger which will be utilized to charge the battery bank in the vehicle. It will fully charge the entire battery bank in less than 5 hours. A user manual will be provided along with all the design reports and milestone statuses of the progressing project. In addition, the final project reports and manual will be delivered April 18, 2011.

# Proposed Design

## Overview

Note that the major components of the Block Diagram when explained are in colored font. This occurs in Section 2: Proposed Design and Section 3: Statement of Work.



 The design of the formula hybrid vehicle can be broken down into three main subcategories as shown above; these include the drivetrain, chassis, and management of the energy usage. The drivetrain will be made up of the internal combustion engine, electric motor, and differential. The internal combustion engine and electric motor will be the two power sources for the vehicle and will be coupled together through the differential in a parallel hybrid setup. The management of the energy that is to be used by the vehicle will need to be carefully engineered. To do this, the vehicle will be equipped with a battery management system, a motor controller, and an array of sensors. The battery management system will make sure that the batteries are being used in an ideal fashion, while the motor controller will do the same for the electric motor. Sensors on the combustion engine will give the driver details on the engine’s performance so he or she can ensure optimal performance from the engine. The last main category of the vehicle’s design is the chassis. The chassis of the vehicle includes the suspension, steering, body, and brakes. The steering system will be a simple rack and pinion design, while the suspension will be an independent double wishbone design. The brakes to be used will consist of two sets of outboard disk brakes and the front and rear axles.

**2.2 Drivetrain**

The drivetrain of the hybrid vehicle is the most important aspect to be considered. The drivetrain is responsible for generating and distributing all of the power needed in order to produce the desired motion and performance of the vehicle. This will be accomplished using an internal combustion engine, an electric motor, and a differential.

**2.2.1 Differential**

The vehicle’s differential is responsible for distributing its input motion directly to the rear axle and then to the wheels. The input motion to the differential comes from the internal combustion engine and the electric motor via two chain drives. A sprocket is to be mounted rigidly to each side of the differential and connected to the motor and engine sprockets via two separate chains. Options for the differential include one designed and fabricated by the team or one taken from the small vehicle, such as an ATV or racing go-cart.

**2.2.2 Internal Combustion Engine (I.C.E.)**



The internal combustion engine is one of two power sources for the vehicle. The engine is predominantly used while operating the vehicle at higher speeds due to its high-speed fuel efficiency. The internal combustion engine receives its fuel from a connected fuel tank and delivers its output to the differential via a chain drive.

**2.2.2.1 Transmission**



The transmission for the internal combustion engine is responsible for dividing the motion delivered by the output shaft of the engine into the correct amount of speed and torque. This is accomplished with a series of gear ratios inside the transmission. Depending on the gear selected by the driver, the appropriate amount of speed and torque will be delivered to the differential. The internal combustion engine being used has the transmission already built into it, thus eliminating the need to find one.

**2.2.2.1.1 Clutch**

The clutch on the internal combustion engine is responsible for engaging and disengaging the engine’s flywheel with the input shaft to the transmission. This is done using a friction pad that is pushed against the engine’s flywheel, thus causing the engine output shaft and the transmission input shaft to spin at the same speed. This clutch is built into the engine itself and will have a mechanism run to the steering wheel to allow the driver to control it. Options for engaging and disengaging the clutch include a pull-wire design and an electrical-actuation design.

**2.2.2.1.2 Gear Shifters**

The gear shifters will be responsible for allowing the driver to decide when to change gears in the internal combustion engine. These shifters will be in the form of paddle shifters mounted to the backside of the steering wheel. When a paddle is pressed, the transmission will change the gear as desired by the driver. Options for the connecting the gear shifters to the engine include a pull cable design and an electrical-actuation design.

**2.2.2.2 Throttle**

The throttle for the internal combustion engine will allow the driver to open and close the throttle valve on the engine itself when more or less power is needed. Throttle cables will be run from the engine’s throttle valve to the gas pedal at the front of the vehicle to allow this interaction to happen. When the pedal is pressed, the cable will be pulled and will force the engine’s throttle valve to open.

**2.2.2.3 Gas Tank**

The gas tank for the internal combustion engine will serve as the fuel reservoir for the engine. The tank will be mounted to the chassis above the engine and will be connected to the engine via the fuel lines. The engine to be used has a matching fuel tank with it, eliminating the need for the team to acquire one.

**2.2.2.4 Radiator**

The radiator for the internal combustion engine will serve the purpose of cooling the engine while it is running. This is achieved mostly through convection. When the car’s coolant is run through the engine, it absorbs the excess heat. The coolant is then run through the radiator, where it is cooled down by the convection provided by air flow that’s created as the vehicle moves. In order to maximize the radiator’s efficiency, it must be mounted perpendicular to the air flow. The radiator that will be used was previously acquired by last year’s team.

**2.2.3 Electric Motor**

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The electric motor is the second power source for the hybrid vehicle. The electric motor is to be used primarily for acceleration and supplementary torque generation. This is due to the fact that the electric motor can provide instant torque when the throttle is pressed, thus making it ideal for acceleration. The current setup for the motor controller, as designed by the previous year’s team, controls the electric motor to match the speed of the internal combustion engine and adds additional torque to the wheels. The electric motor receives its energy from the batteries and supplies its output to the differential via a chain drive. Just as with the internal combustion engine, the electric motor’s output sprocket is connected to the differential via a chain and sprocket.

**2.2.3.1 Electric Throttle**

The electric throttle allows the user to control how much power the electric motor is outputting. This is done with an input lever that was acquired by the previous year’s team. When the electric throttle is pressed, a signal is sent to the motor controller which then dictates what the motor will do.

**2.3 Energy Management**

The energy management aspect of this vehicle has to be carefully considered as it is will determine the team’s performance in the competition. Being a formula hybrid competition, many of the challenges are based on energy consumption. Being efficient in the use of the allotted energy will increase performance in the competition. The energy management aspect of the design will be broken into three sub categories: the battery management system, the motor controller, and the internal combustion engine.

**2.3.1 Battery Management System**

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The battery management system is responsible for making sure that the batteries in the vehicle are all charged and discharged equally. This means that no one battery will be used more than another. This will be accomplished using a programmed microcontroller and voltage and current sensors. The voltage and current sensors will relay the levels of each battery back to the controllers. The programming of the controller will then dictate which batteries, if any, need to be charged or discharged first. Options for the battery management systems include purchasing one already programmed or designing and creating one as a team.

**2.3.1.1 Batteries**

The batteries serve as the energy storage for the electric motor. They are pre-charged using a separate charging unit and then discharge the energy to the motor as current. The batteries to be used were acquired last year and consist of 32 lithium-ion battery packs.

**2.3.1.2 Sensors**

 The sensors for the battery management system are used to convey the information from the batteries to the controller of the battery management system. The sensors to be used include voltage and current sensors. These will be coupled to each battery pack and will then relay the batteries voltage and current levels to the controller.

**2.3.2 Motor Controller**



 The motor controller on the hybrid vehicle will be responsible for the controlling of the electric motor. This includes telling the motor how much current it needs to draw from the batteries in order to output the correct torque and speed as requested by the driver via the electric throttle. This will be accomplished by using a programmed controller. The motor controller that will be implemented is the same as the one that the previous team selected.

**2.3.2.1 Programming**

 The programming for the motor controller will be responsible for the actual decision-making. This will be accomplished by using C++ language. The programming of the controller was already implemented by the previous year’s team, although slight modifications might be necessary when incorporating the internal combustion engine.

**2.3.3 Internal Combustion Engine**

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 Management of the internal combustion engine will be implemented in order to achieve maximum efficiency from the engine while it is in operation. This is going to be done using an array of sensors that will convey the engine’s status and performance to the driver.

**2.3.3.1 Sensors**

The sensors for the internal combustion engine will allow the driver to easily tell how the internal combustion engine is behaving at any given time during its operation. This will be accomplished by linking the sensors to easy-to-read dials on the vehicle’s dashboard. The driver will then be able to use this information to adjust his or her driving habits to maximize the engine’s performance and efficiency. Important sensor options include those that can measure the engine’s number of revolutions per minute, its velocity, its temperature, and the amount of fuel left in the gas tank.

**2.4 Chassis**

The definition for the chassis of a vehicle varies but for the remainder of this report the chassis will refer to all of the mechanical components of the vehicle that are not responsible for power generation or transmission. The vehicle’s chassis includes the frame of the vehicle, the braking systems, the body of the vehicle, the suspension, and the steering system.

**2.4.1 Steering**

The steering system is responsible for allowing the driver to control the direction of the vehicle through the use of a steering wheel. The steering system implemented by the previous year’s team, which will be the system used this year as well, is a rack and pinion steering system. The components included in this steering system are the rack, steering wheel, tie rods, hiem joints and the clevis rod. When the driver turns the steering wheel, a pinion at the end of the steering wheel shaft rotates and pushes the rack either to the left or right via its teeth. This rack motion then pushes on the tie rods, connected via the clevis rod. The tie rods transmit this motion through the hiem joints and to the steering knuckle on the vehicle’s uprights, which thus turns the wheels accordingly.

**2.4.2 Suspension**

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The suspension system of the hybrid vehicle will be responsible for keeping the vehicle stable while it is undergoing erratic motion and the resulting dynamic weight transfers. This will be accomplished using an independent double wishbone suspension system for all four of the tires. The current design on the vehicle will be used again with slight modifications. Modifications include but are not limited to replacing the hollow rods used for the control arms with solid rods.

**2.4.2.1 Front Suspension**

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The front suspension will consist of an independent double wishbone system on each wheel to allow for stabilization during dynamic weight transfers.

**2.4.2.1.1 Control Arms**

The control arms on the front suspension will serve as the connection between the frame of the vehicle and the uprights (discussed next). These arms are the structural members of the suspension and are what transmit the forces from the road to the springs and shocks of the suspension system. The shocks in the suspension system act as dampers by removing energy from the suspension, while the springs simply return the suspension to its neutral position. The springs and shocks acquired last year are adequate for continued use and thus will not need to be modified. The current control arms on the vehicle will need to be replaced with ones made of solid rod as opposed to hollow.

**2.4.2.1.2 Uprights**

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The uprights of the vehicle are responsible for attaching the tires to the suspension and transmitting the load from the ground (through the tires) to the control arms. This is accomplished by mounting the uprights to the axle of the tire and attaching the suspension to the opposite side of the uprights via hiem joints. The current uprights will need to be redesigned for the next competition. Possible modifications include material selection and size reduction.

**2.4.2.1.2.1 Tires**

The tires of the vehicle will be the main coupling point between the vehicle and the road. Because the tires are the only part of the vehicle that are in contact with the road, all forces will be transmitted through them. This includes the forces due to acceleration and deceleration of the vehicle, as well as the ground reaction forces caused by the weight of the vehicle. The ground reaction forces will be transmitted to the struts whereas the acceleration forces, transmitted to the road via friction, will be directly absorbed by the tires through the wear of the tires. Current tires will be used again with the possibility of acquiring a rain-proof set.

**2.4.2.2 Rear Suspension**

The rear suspension will be identical to the front suspension in design. The only difference between the two is that the rear suspension will be responsible for handling heavier loads as the rear of the vehicle has more weight than the front. This results in greater acceleration and deceleration forces as well as larger ground reaction forces.

**2.4.3 Body**

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The body of the vehicle will serve as the main structure and foundation where everything else will be attached. The complete body of the vehicle will consist of an underlying frame with a nose cone attachment at the front.

**2.4.3.1 Frame**

The frame of the body will be the main support of the vehicle and will serve as the bottom layer foundation. The frame is essentially the ground of the vehicle where everything can attach securely. The frame is also responsible for distributing any external forces applied to the vehicle evenly and safely throughout itself in order to minimize component damage. The current frame was sufficiently designed to do this using a truss-like approach.

**2.4.3.2 Nose Cone**

The nose cone of the vehicle will reduce the overall drag of the vehicle by creating a smooth surface at the front. This smooth shape design will allow air to easily flow over the front of the vehicle in a laminar fashion, thus reducing the vehicle’s overall drag.

**2.4.4 Brakes**

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The braking system of the vehicle will allow the driver to slow down the car and bring it to rest through the application of a friction force to the axle of the vehicle. This will be accomplished using a separate braking system at both the front and the rear of the car. All braking systems used will be traditional disk brake systems as these are optimal for the application of our vehicle. Each braking system will consist of a master brake cylinder, brake lines, and brake calipers.

**2.4.4.1 Front Brakes**

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The braking system in the front of the vehicle is the most important because this is where the majority of the braking force is needed. When a vehicle is decelerated through braking, the weight in the rear of the vehicle is transferred to the front of the vehicle. As a result due to this dynamic weight transfer during the braking process, more braking force is needed at the front of the vehicle in order to lock up the wheels as required by the competition. This braking force is determined by the master cylinder.

**2.4.4.1.1 Front Master Cylinder**

The master cylinder is the key component to look at when designing a brake system. The master cylinder determines how much pressure is going to be inside the brake lines and thus how much force is going to be applied to the brake pad. Since pressure is equal to a force divided by an area, a smaller master cylinder area will generate a higher brake fluid pressure. This allows the designer of the system to dictate how much braking force will be applied to each set of wheels. The piston inside of the master cylinder is connected directly to the brake pedal. As the pedal is pushed by the driver, the piston moves and creates a pressure inside of the brake lines. This pressure is then transmitted to the calipers where it is used to generate a braking force. The master cylinder selection will be determined once the amount of force required to stop the vehicle is determined.

**2.4.4.1.2 Front Brake Calipers**

The brake calipers consist of a housing that holds the brake pads and the pistons that act on the pads. The calipers are attached to the rotors which are attached rigidly to the wheels. The calipers are responsible for converting the brake fluid into a stopping force on the rotors. The pressurized brake fluid is transferred to the calipers via the brake lines. This pressure is then routed to the pistons that act on the brake pads. The pressure in the brake lines creates a force on the pistons that then acts on the brake pads. This causes the brake pads to be pressed against the rotors, thus creating a braking force that will stop the vehicle. The specific calipers needed are determined by the amount of force required to stop the vehicle. Options include calipers with different brake pad sizes and with different numbers of pistons acting on the pads.

**2.4.4.2 Rear Brakes**

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The rear braking system design will be very similar to the one used for the front braking system. Disk brakes will still be used and they will still function in the same manner as the front brakes. The difference with the rear brakes is that they will not need to generate as much braking force as the front system. As stated before, this is because weight is transferred to the front of the vehicle when braking.

**2.4.4.2.1 Rear Master Cylinder**

The master cylinder for the rear braking system will perform the same function as the ones in the front systems except to a lesser extent. Since less force is required at the rear wheels of the vehicle, the rear master cylinder will be larger than the front master cylinder. This will create a lower pressure in the brake fluid and thus generate a lower force on the brake pads.

**2.4.4.2.2 Rear Brake Calipers**

Again, the brake calipers will perform just as the front calipers do. The difference with the rear calipers is that it will not be necessary to generate as much force in the rotors as the front calipers do. This means that options for the rear calipers include ones with less pistons acting on each brake pad or ones with smaller brake pads.

# Statement of Work (SOW)

***3.1 Task 1: Project Management***

**3.1.1 Objectives**

In an effort to complete and address the tasks expected, the formula hybrid car team would need to follow through with what was left undone from the original design specifications and implementations made by last years team. On top of this there are also new initial design ideas, the implementation of those ideas, the integration of new parts and additions to old parts as well as tests for efficiency and demonstrations of the car to make sure it is ready for the formula hybrid competition. The competition will have multiple courses that test the different speculations of the car but the main course will be somewhat of a racetrack that the car must complete in a given amount of time.

**3.1.2 Approach**

In order to accomplish our objective, the car will be divided into sections amongst the group based on what needs to be completed: differential, electric coupling, ICE incorporation, regenerative braking, and the suspension. Adding onto that, the teams will also be divided based on technical areas: computer programming and sensors, mechanics, and electric/wiring. Each member is required and expected to keep up with the task they’ve been given and stay up to date with each goal they are expected to complete. The responsibilities necessary for each team member will be explained to detail in section 5 (Qualifications).

***3.2 Task 2: Problem Design and Implementation***

**3.2.1 Objectives**

The objective of this task is to describe how the main components of this design will be designed and implemented. The formula Hybrid car is expected to look and run in a certain manner and it is the team’s job to make sure that the car does that. More detail on how the team will carry out this mission can be found in the approach section.

**3.2.2 Approach**

There are a couple of different ways to go about completing the design and implementation. From a very general stance, they can be split into categories such as: planning, drawing schematics, building/wiring/coding and molding. In another more technical stance, they can be split into categories such as: power and energy storage, electric/ICE coupling, and braking.

The implementation will be broken in to technical committees, which will be responsible for each component of the technical area. The technical committees are the Suspension Committee, Battery Management Committee, Drive Train Committee and Sensor Committee. Each respective committee will determine what device will be purchased, how they will be implemented and testing among each.

**3.2.2.1 Drivetrain**

**3.2.2.1.1 Objectives**

The drivetrain will be couple power generated by the electric motor and the internal combustion engine. In addition, it will deliver to the road surface through the differential quite efficiently.

**3.2.2.1.2 Approach**

The completion of an efficiently operating drivetrain will be a combined effort from all current team members on the 2011 Formula Hybrid Team. The electrical engineering students will be striving to maximize the functionality of the electric motor. Also the electrical team will ensure that there is no chance of overpowering the motor and subsequently ruining it. The mechanical engineering students will focus on the installation and incorporation of the internal combustion engine and its components into the drivetrain. Attention will be devoted to the coupling of the ICE with the electric motor throttle, clutch, and gear shifting capability of the ICE.

**3.2.2.1.3 Test/Verification Plan**

The functioning of the drivtrain under electric power only, mechanical power only, and the combination of the two will be tested and evaluated through a series of dynamic tests, i.e. autocross, endurance, and acceleration. These different conditions will directly replicate how the vehicle will behave during the SAE Formula Hybrid Competition.

**3.2.2.1.4 Outcomes of Task**

The vehicle operates smoothly and is capable of being powered by more than one source acting solely or by two sources acting in unison.

**3.2.2.1.1.1 Differential**

**3.2.2.2.1.2 Objectives**

The objective of this task is to couple and transmit torque and rotation from the electric motor and ICE. To achieve this task, the mechanical engineers will combine the unequal transmitted torque from the ICE and electric motor into one uniform torque, which can be applied to one output shaft.

**3.2.2.2.1.3 Approach**

The mechanical engineers Ryan, Thomas, and Philip will be responsible for performing this task.The electric motor and the combustion engine will be directly linked to the differential casing. The driven sprockets will be mounted on the outside of the differential casing with the sprocket driven by the electric motor on one end of the differential and the driven sprocket from the combustion engine on the other side. A disc brake that is mounted around the center of the differential will be removed to provide room for the sprockets. The driven sprocket from the combustion engine has been fabricated to provide the desired gear ratio and will be installed. The electric motor is in place and currently driving the differential.

**3.2.2.2.1.4 Test/Verification Plan**

The bulk of this test will be done by FEM and Pro-e ensuring the differential can withstand the increased loads from the ICE. Testing will be done to ensure that the differential casing is strong enough to withstand the stresses induced by the torque provided from the engines. Measuring devices will be used to ensure proper alignments of the driving and driven sprocket of the ICE.

**3.2.2.1.1.5 Outcomes of Task**

Direct coupling of the electric and combustion engine will be accomplished providing a method to output the torque to the drive shaft by means of the differential. The internal combustion engine will be integrated into the system.

**3.2.2.1.2.1 Internal Combustion Engine (ICE)**

**3.2.2.2.2.2 Objectives**

The objective is to provide power and a secondary means of acceleration to the formula hybrid vehicle at high speeds, when the electric motor is highly inefficient. The incorporation of an internal combustion engine is essential to qualify for the competition.

**3.2.2.2.2.3 Approach**

A Kawasaki Ninja 250 cc internal combustion motorcycle engine has been acquired and will be installed into the vehicle. Each component of the engine will be treated separately such as the clutch, exhaust, gas tank and radiator. Mounts and connections for the motor are currently in place. Ryan, Thomas, and Philip will accomplish this task.

**3.2.2.2.2.4 Test/Verification Plan**

The engine will be tested before it is installed into the vehicle. This approach will allow us to fix any problems encountered more easily because the engine and its components will be more accessible. Secondary testing consisting of verifying that all of the engine’s components are working properly will occur when the engine is mounted on the chassis of the vehicle. The mechanical engineers on the team are responsible for ensuring that this is complete.

**3.2.2.1.2.5 Outcomes of Task**

Two different motors will power the formula hybrid vehicle and one of the many qualifications for the competition will be completed. A greater amount of power will be provided to the vehicle and the overall speed will increase.

**3.2.2.1.3.1 Transmission**

**3.2.2.1.3.2 Objectives**

The transmission will provide a method of controlling the output shaft of the ICE. The driver will be able to easily change gears and operate the engine.

**3.2.2.1.3.3 Approach**

The transmission consists of a clutch and gearbox that are integrated into ICE. The clutch will operate the transmission by means of a foot pedal. The foot pedal is installed and the clutch cable will be attached. Paddle shifting will be used to change gears and will be located on the steering wheel. Ryan, Thomas, and Philip will accomplish this task.

**3.2.2.1.3.4 Test/Verification Plan**

The transmission will be tested by ensuring that the engine changes gears and is responsive. Ryan, Thomas, and Philip will accomplish this task.

**3.2.2.1.3.5 Outcomes of Task**

The operator is capable of easily shifting gears and controlling the ICE. A method of transferring between electric power and mechanical power is available because of a properly working transmission.

**3.2.2.1.4.1 Radiator**

**3.2.2.1.4.2 Objectives**

The objective of the radiator is to transfer thermal energy from the engine to the surroundings and prevent engine overheating.

**3.2.2.1.4.3 Approach**

Competition regulations require that all coolants be plain water. The radiator will be cooled by water and mounted securely in the rear of the vehicle.This task will be verified by Ryan, Thomas, and Philip

**3.2.2.1.4.4 Test/Verification Plan**

Testing will be accomplished using the temperature sensors incorporated into the ICE. Proper measurement observations will be attained before operating the ICE at high RPM’s to prevent any possible overheating.This will be accomplished by Ryan, Thomas, and Philip.

**3.2.2.1.4.5 Outcomes of Task**

The engine will cool properly and not overheat. Qualifications for competition will be met for coolant used and secure mounting of the radiator.

**3.2.2.2 Energy Management**

**3.2.2.2.1 Objectives**

The main objectives of the Energy Management component include the Battery Management System, the Microcontroller and the overall programming for these devices.

**3.2.2.2.2 Approach**

The battery management system will be designed, tested and implemented by Stephanie Medina, Israel Daramola and Lorenzo Neal. They will be in charge of ensuring the batteries are all discharging at the same rate. In addition, they will be managing the microcontroller completion for the coupling between the electric motor and internal combustion engine.

**3.2.2.2.3 Test/Verification Plan**

This task will be verified by one computer engineer such as Stephanie Medina and the two electrical engineers known as Lorenzo Neal and Israel Daramola. To test and verify the BMS, the teammates will ensure that the company’s component is compatible with the vehicle once received and installed. The microcontroller will be tested by the loading the program onto the device and monitoring that it fulfills all necessary functions.

**3.2.2.2.4 Outcomes of Task**

After the completion of this task, the vehicle will be able to conseve energy and manage the different components of energy efficiency. In addition, once the installation of the microcontroller is completed, the microcontroller will manage when the internal combustion engine is to be utilized and when the electric motor will be used.

**3.2.2.2.1.1 Battery Management System**

**3.2.2.2.1.2 Objectives**

The objectives of the BMS involve the managing of the rechargeability of the battery packs. The BMS device will also monitor, protect and balance the state of the battery packs.

**3.2.2.2.1.3 Approach**

The approach that will be taken for this system is primarily to look at different design options and decide on the best fit. In order to do so, more in depth research will be conducted by the electrical and computer engineering teammates. After haven chosen the best fit for the vehicle, the next step will involve testing the BMS to match the formula vehicle design. So far the best option is the Elithion-Lithiumate Battery Management System, which has several attractive features to it. These advantages include the system being quite versatile, extremely safe, easy to install and life prolonging.

**3.2.2.2.1.4 Test/Verification Plan**

As mentioned earlier, our best option is the Elithion-lithiumate BMS. In order to test this system, the team will need to install it into the vehicle first and assure that it functions properly. The idea is to set it to work properly with one cell on the battery and once having proved so, test it with a couple other cells on the batteries. These batteries will also be hooked up to a resistor to ensure that the most amount of current is produced and once having done so, that the BMS shuts the battery packs off. Stephanie Medina, Lorenzo Neal and Israel Daramola will be in charge of testing the integration of the BMS.

**3.2.2.2.1.5 Outcomes of Task**

The outcomes for the BMS will be to assist the prolonging of battery life and to monitor the voltage and current from each battery. By the BMS achieveing these two main tasks, the two main problems of the uneven charging of cells on the batteries and the danger of the unacceptable voltage level being reached, will be resolved.

 **3.2.2.2.1.1.1Sensors**

**3.2.2.2.1.1.2 Objectives**

There are many objectives for the sensors on the formula hybrid car. This year the group plans on integrating sensors for the Battery Management system (BMS), speedometer, sensor to measure RPM, and fuel gauge. The Majority of the sensors that are going to be used will be for the BMS. The BMS system consists of multiple current and voltage sensors so that the BMS can analyze each battery and provide each it with an equivalent amount of voltage. The speedometer sensor will be used to inform the driver of the rate of speed that her/she is traveling at a given time. The RPM sensor will also function similarly to the speedometer with the only difference being hat this sensor will relay information regarding the RPM of the ICE.

**3.2.2.2.1.1.3 Approach**

The approach of the sensors will be that the electrical and computer engineers Lorenzo Neal (E.E), Isreal Daramola (E.E), and Stephanie Medina (C.E) will research many different types of current, voltage, speedometer, and RPM, sensors. The manufacturing company that makes the BMS system will be contacted to inform the team of some compatible sensors for their specific BMS. Sensors for the speedometer and RPM will be researched and the most effective and affordable sensor will be utilized.

**3.2.2.2.1.1.4 Test/Verification Plan**

The test plan for voltage and current sensors will be to use a small voltage source in series with a single resistor. The student will place the voltage sensor in parallel to the resistor and determine if the voltage relayed by the sensor is equivalent to the input voltage. The current sensor will be tested in a similar way but the difference will be that the current sensor will not be in parallel with the resistance, it will be in series with the resistor. Once the current is relayed by the sensor, the user will verify that the current and voltage that the two sensors measures are accurate by measuring the voltage and currents with a voltmeter and ammeter. The test plan for the speedometer and RPM sensor will be implemented by installing the sensors on the car. Once the sensors are properly installed, the driver of the hybrid will follow a driver in the vehicle who will reach a constant speed. More so the individual will determine if the speedometer installed on the hybrid is equivalent to the speed at which the hybrid is traveling.

**3.2.2.2.1.1.5 Outcomes of Task**

The outcome of the sensors will be that the BMS is working correctly and that the correct speed and RPM will be relayed to the driver.

**3.2.2.2.2.1 Motor Controller**

**3.2.2.2.2.2 Objectives**

The main objectives of the microcontroller involve the controlling and providing of torque to the electric motor. The purpose of the torque control is to aid the acceleration of the vehicle by providing constant torque. The motor controller will also be the major component in regenerative braking, since it controls the electric motor. This electric motor will charge the batteries when not being used for acceleration.

 **3.2.2.2.2.1.1 Programming**

**3.2.2.2.2.1.2 Objectives**

The objectives for the programming refer back to the incorporation of the Internal Combustion Engine throttle and getting it in sync with the electric motor throttle to make one full pedal. The programming will involve the controlling of when to switch between the two engines.

**3.2.2.2.2.1.3 Approach**

The approach that will be taken for the programming of the microcontroller is to set up both the ICE and the electric motor separately and ensure that they both function properly. In addition, once the proper functioning of the both engines has been fulfilled, the two engines will be programmed in C++ code to be integrated with another.

**3.2.2.2.2.1.4 Test/Verification Plan**

The testing plan to be completed for the microcontroller will be the breaking down of code by utilizing Glass-Box and Black-Box Testing. Glass Box Testing basically tests the internal features of a component. Once the glass-box testing has been fulfilled and the code is proven to be working properly, black box testing will be used to test and analyze the overall component as a whole.

**3.2.2.2.2.1.5 Outcomes of Task**

The outcomes of this task involve the main purposes of the Microcontroller being completed. The Microcontroller will control when both or either engine is to be used between the electric motor and internal combustion engine.

**3.2.2.3 Chassis**

**3.2.2.3.1 Objectives**

The vehicle’s chassis must be able to maneuver and withstand high speed turns while passing a full inspection by a licensed Formula Hybrid Judge.

**3.2.2.3.2 Approach**

The task of ensuring the strength and maneuverability of the chassis will fall to the current mechanical engineers on the Formula Hybrid Team. The team consist of, Thomas Emerick, Philip Young and Ryan Zombek. With the assistance of several computer aided design programs, the team plans on analyzing the chassis in depth, while maximizing strength and minimizing weight. To ensure maneuverability, the team will perform engineering analysis on the frame, suspension and braking system.

**3.2.2.3.3 Test/Verification Plan**

The method in which the vehicle’s chassis will be tested will begin by a rigorous full body inspection by the complete Formula Hybrid Team. Each member will be responsible for ensuring the specifications stated in the 2011 Formula Hybrid Rulebook for Chassis, primarily sections 3.3–3.4. The chassis will also be tested in several CAD packages that allow the engineers the ability to analyze the stress and strain throughout the chassis. As for a dynamic chassis test/verification plan, the team plans on doing complete trial runs for each major category of performance, i.e. acceleration, endurance and autocross. If the vehicle passes these categories under the specified required time, the group will consider the chassis for the vehicle complete.

**3.2.2.3.4 Outcomes of Task**

Upon completion of this task, the vehicle’s chassis will be complete and race ready. All major components will have been designed, tested and implemented to ensure the highest level of competiveness in the Formula Hybrid Race in May, 2011.

**3.2.2.3.1.1 Frame**

**3.2.2.3.3.2 Objectives**

The objectives of the frame is to analyze the structure of the car and to strengthen it as required, insuring that it will handle the additional stresses caused by the added weight of the internal combustion engine and its components.

**3.2.2.3.3.3 Approach**

Ryan Zombek, Philip Young and Thomas Emerick will be designing, testing and implementing any changes to the frame itself. First, the whole frame will be modeled in Pro-Engineering and COMSOL, compensating for the additional weight of the ICE and its components. Next, the team will use Finite Element Analysis to analyze the stress loads throughout the body of the frame itself. Upon obtaining this knowledge, as a group we will make an engineering decision on if the frame can withstand the added weight and if modifications are needed.

**3.2.2.3.3.4 Test/Verification Plan**

The test for this subtask will be based on the calculations and analysis of the frame as modeled in Pro-Engineering and COMSOL. After analysis the mechanical engineers on the team will make an engineering decision on whether the modeled frame will be a suitable sturdy, reliable formula racecar frame.

**3.2.2.3.3.5 Outcomes of Task**

After the completion of this task, the frame of the vehicle will be competition-ready. In addition, it will have compensated for the added weight of the internal combustion engine.

**3.2.2.2.1.1.1 Nose Cone**

**3.2.2.2.1.1.2 Objectives**

The objective is to retrofit the vehicle with a front nose cone to reduce drag and to make our vehicle more energy efficient at higher speeds.

**3.2.2.2.1.1.3 Approach**

The nose cone will be designed, tested and implemented by Ryan Zombek, Thomas Emerick and Philip Young. Taking the raw dimensions of the front frame of the vehicle, each team member will model their own nose cone in Pro-Engineering. Next, each member will calculate the coefficient of drag for their model and the group will make a decision on what model is the best, taking into consideration the overall weight of the nose cone and also the drag coefficient of the design.

**3.2.2.2.1.1.4 Test/Verification Plan**

This subtask will be tested and based from the calculations made in Pro-Engineering. Once the group is equipped with a coefficient of drag from the prototype, a comparison can be made to an average open-wheeled vehicle’s coefficient of drag which is approximately 0.6. To pass the test for this subtask, the team placed a standard of 0.5 on the coefficient of drag for the Formula Hybrid Vehicle’s front nose cone

**3.2.2.2.1.1.5 Outcomes of Task**

After completion of this task, the vehicle’s front nose cone will comply with the 2011 Formula Hybrid Rulebook as stated in section 3.4 and have a drag coefficient lower than 0.5, making it more energy efficient at high speeds than typical open-wheel vehicles.

**3.2.2.3.2.1 Suspension**

**3.2.2.3.2.2.1 Objectives**

The suspension should be lightweight and should allow for two inches of usable wheel travel, allowing for maximum one inch jounce and once inch rebound.

**3.2.2.3.2.2.2 Approach**

The vehicle’s suspension will be designed, implemented and tested by Ryan Zombek, Thomas Emerick and Philip Young, the mechanical engineer’s on the team. Each team member will make calculations based on important factors such as the added weight of the internal combustion engine and its components such as exhaust and fuel tank. Using ADAMS software, each team member will then model the suspension using the critical numbers from the calculations mentioned above. From this, appropriated spring constants for the suspension can de deduced.

**3.2.2.3.2.2.3 Test/Verification Plan**

The suspension will be tested in two categories, static and dynamic. For the static test a 200 lb sand bag will be placed in the driver position, while simultaneously taking measurements on the spring’s deflection to ensure a maximum one inch jounce and one inch rebound. For the dynamic test, the team will perform autocross trial runs to ensure the vehicle can maneuver high speed turns effectively.

**3.2.2.3.2.2.4 Outcomes of Task**

When the task is complete, the vehicle will be able to maneuver and withstand high speed turns with maximum one inch jounce and one inch rebound.

**3.2.2.2.3.2.1.1 Uprights**

**3.2.2.2.3.2.1.2 Objectives**

The uprights shall connect the CV joint from the chassis to the wheel hub and brake system of the vehicle. The uprights will create a strong connection between the wheels and the chassis.All four uprights must be lightweight yet be able to withstand significant stresses and strains

**3.2.2.2.3.2.1.3 Approach**

The vehicle’s uprights will be designed and tested by the mechanical engineers on the team. However the testing and implementing will be conducted by the whole 2011 Formula Hybrid Team. Design ideas will be generated by researching pact competitor’s upright designs and implementing the team’s need into those designs. Features such as strut spacing, brake size, mounting and most importantly in this case, weight will be considered when creating models in various CAD packages.

**3.2.2.2.3.2.1.4 Test/Verification Plan**

The verification of this subtask will mostly be based on the Finite Element Analysis of the uprights from COMSOL. The mechanical engineers on the team will analysis the results from the FEM model to ensure the uprights can withstand the forces generated on them that the team demands. Once all members agree on a model, the group will implement it. After implementation the vehicle will be put through a series of dynamic events, i.e. acceleration, autocross and endurance to ensure the vehicle can withstand high speed turns effectively.

**3.2.2.2.3.2.1.5 Outcomes of Task**

After completion of the uprights, the formula hybrid team will be able to successfully mount all four wheels to the CV joints that are directly linked to the chassis itself. The uprights will also be compliant with the 2011 Formula Hybrid requirements specified by section 3.2, while still ensuring the highest level of competitiveness in this competition.

**3.2.2.3.2.2 Steering**

**3.2.2.3.2.2.1 Objectives**

The steering system must have positive steering stops that prevent the steering linkages from locking up. Also the allowable steering system free play will be limited to 7 degrees total measured at the steering wheel.

**3.2.2.3.2.2.2 Approach**

Since the mechanical engineers on the team have knowledge on linkages and mechanical systems, they will be responsible for the completion of this subtask. The group will implement a steering stop on the rack and pinion of the vehicle to prevent the tires from rotating too far and hitting any part of the car.

**3.2.2.3.2.2.3 Test/Verification Plan**

The verification of this task will be conducted by the whole Formula Hybrid Team. Tests will be conducted by turning the steering wheel to its maximums points on the rack and pinion system, while ensuring there is no contact between the steering linkages and the wheel itself.

**3.2.2.3.2.2.4 Outcomes of Task**

Upon the completion of this subtask the vehicle will have positive steering stops that prevent the steering linkages from locking up. Also the allowable steering system free play will be limited to 7 degrees total, which is measured at the steering wheel.

**3.2.2.3.2.3 Brakes**

**3.2.2.3.2.3.1 Objectives**

The vehicle must demonstrate the capability of locking all four wheels and stopping in a straight line at the end of an acceleration run. The brake pedal must also be designed to withstand a force of 2000 N without any failure in the brake system or pedal box.

**3.2.2.3.2.3.2 Approach**

The vehicle’s brake system will be designed, tested and implemented by the mechanical engineering team. The best way to approach this subtask would be to get the vehicle close to maximum speed and then slam on the brakes. By measuring the braking distance, values such as braking force, brake fluid pressure and disc caliper-piston pressure can all be deduced. From this analytical approach, the mechanical engineers will be able to properly choose a braking system that suits the needs of this competition best.

**3.2.2.3.2.3.3 Test/Verification Plan**

The vehicle’s braking system will be tested through a series of dynamic tests that directly represent what the team will be asked to demonstrate in May during the 2011 Formula Hybrid competition.

As for testing the pedal box to withstand a 2000 N force, the mechanical team will place a pre-calibrated actuator to displace exactly 2kN of force onto the pedal box itself. If the pedal box passes this test, this subtask is complete.

**3.2.2.3.2.3.4 Outcomes of Task**

After completion of this task the vehicle will have the capability of locking all four wheels and stopping the vehicle in a straight line at the end of an acceleration run. The brake pedal will also be able to withstand a 2000 N force applied to it, without any failure to the brake system or pedal box.

**3.2.3 Test Verification Plan for Task 2**

The group decided on major issues to address this year and sequentially broke that up into individual manageable tasks that could be tested and verified. Please see Reference Test/Verification Plans above for details on each component.

## Documentation

The Formula Hybrid Car Team will be submitting to the Formula Hybrid Committee at the Competition on May 01, 2011 the following:

* + Final End of Year Report
	+ Structural Equivalency Form
	+ Attenuator Information
	+ Schematic of the High Voltage Electric System
	+ Detailed Electrical Schematic of Internal Circuit
	+ Electrical Safety Report
	+ Vehicle Drawings
	+ Design Report
	+ Design Spec Sheet Format
	+ Weekly Minutes
	+ Designated Driver Documentation
		- Medical Insurance
		- Car Insurance
		- Driver’s License
		- Clean Bill of Health ( No health problems)
		- SAE Membership

#

# 4 Risk Assessment

There are many risks associated with the Formula Hybrid Car project. The primary risk that impacts the project the most is the risk of running out of time. The likely hood of this risk becoming a reality that is very high and it depends on many factors. One factor that might greatly reduce the amount of time that the team has will be the shipment time of the products that are ordered throughout the semesters. This factor is inevitable for the project members. This can benefit or hurt the overall progress of the car.

A second factor that might impinge on the progress of the project will be the health of the team members. If one or more of the team members becomes ill, this will cause other team members to have to work even harder and possibly longer to compensate for the missing member’s work. A third risk factor that may prolong the progress of the project can be a result of insufficient funds due to the lack of funding that is available. This is an important and very likely risk factor for this year’s team. As of right now the team has $5,000 in its budget, it is going to cost $1500 for the competition registration and the BMS that is being considered for the car is in the price range of $3000. Paying for the BMS and Registration will account for over half of the budget that is currently available. Therefore, the possibility of running out of funds is very likely once the team accounts for all of the materials and outside contracting that may be needed upon completion of the vehicle.

Testing of the components can be a benefit as well a risk factor. The testing of the sensors, BMS and other parts will require a lot of testing to ensure that they are functioning in a manner that is beneficial to the overall functioning of the car. The risk aspect of testing becomes a factor when the testing process takes longer than expected, due to error in testing and faulty components that require reordering and retesting. So in order for the team to manage testing so that it will be an asset other that a liability, they must understand how the components or systems work to be able to test them effectively and efficiently.

A final major risk factor that is very likely for the formula hybrid team is the procrastination or spending too much time on a single stage of the car. This is a major risk factor because is has been a major contributor to the reason, why many teams in the past were unsuccessful in completing their project or the fact of having to rush and finish the project hours before the project is due. There are numerous risk factors that may influence the outcome of this project, but the best way that the team can overcome these obstacles is by working hard, helping one another and most of all by remaining focused.

# 5 Qualifications and Responsibilities of Project Team

In order to accomplish the overall objectives of the project, team members were assigned administrative and technical assignments. As mentioned earlier, the team is composed of one computer engineer, two electrical engineering and three mechanical engineering students. These students include Stephanie Medina, Lorenzo Neal, Israel Daramola, Ryan Zombek, Thomas Emerick and Philip Young, respectively. The divisions of the task assignments were designated as the following.

|  |  |  |
| --- | --- | --- |
| **Task**  | **Assignment**  | **Skills and Knowledge**  |
| 1  | **Stephanie Medina** | **Administrative Position:** Project Manager**Technical Position:** Lead Engineer**Technical Assignment:** Completion of Battery Management System |
| 2  | **Lorenzo Neal** | **Administrative Position:**Treasurer**Technical Position:** Electrical Technical Lead**Technical Assignment:** Installing of Microcontroller for ICE w/ Electric Motor |
| 3 | **Israel Daramola** | **Administrative Position:** Secretary**Technical Assignment:** Completion of Microcontroller for ICE w/ Electric Motor |
| 4 | **Thomas Emerick** | **Technical Position:** Mechanical Design Lead**Technical Assignment:**Redesigning of calipers within brakes and restoring of body and shell |
| 5 | **Ryan Zombek** | **Administrative Position:** Rules and Safety Officer**Technical Assignment:** Redesigning of Suspension |
| 6 | **Philip Young** | **Technical Position:** Mechanical Technical Lead**Technical Assignment:** Redesigning of Suspension |

Stephanie Medina is currently a first year senior. Her major is Computer Engineering and she is in charge of the completion of the Battery Management System. Stephanie was assigned the administrative position of Project Manager since she is a very organized individual who likes to stay on top of her assignments. Stephanie has taken courses such as Circuits 1-2, Electronics 1, Programming C++, Objected Oriented Programming, Microprocessors, Field Programmable Logic Devices and is taking Data Structures and Computer Architecture at the moment. Based on her past and current experience with the course load mentioned, she has acquired exceptional circuit analysis and programming skills leading her to be one of the best fit for the Battery Management System.

Lorenzo Neal is a senior this year majoring in Electrical Engineering. Lorenzo is the Treasurer and has been chosen to be the Electrical Technical Lead for this year’s Formula Hybrid team. He is an individual who is very responsible and efficient when it comes to financial matters. In addition, he understands the electrical engineering concepts to an extensive manner. He has taken courses in Electronics I, Electromagnetic Fields, Circuits1-2, Fundamentals of Power Systems, and Analysis and Design of Control Systems. As one can see, having taken these courses, Lorenzo has grasped the skills necessary to fulfill the installation of the ICE, and be able to make the correct adjustments to allow the ICE and electric motor to achieve maximum efficiency.

Israel Daramola is another electrical engineer on the team. This being his senior year as well, he is fulfilling the Secretary position as he is quite competent in taking detailed notes at all meetings and events in regards to the team project. More so, Israel will be handling the completion of the Motor Controller for the coupling alongside with Lorenzo Neal. Israel’s background on the courses of Circuits 1-2, Electronics, Thermodynamics, Engineering Mechanics, Fundamentals of Power, and Electromagnetic 1-2 have given him the essential skills to achieve the goals for this task.

Philip Young, who is another senior on the team, is one of the first Mechanical Engineers on the Formula Hybrid Project. Due to his background in Mechanical System Design, including courses such as Vehicle Design, Mechanical Systems I/II, and Design Using the Finite Element Method, he was voted to be the Mechanical Technical Lead as he has acquired some of the most proficient skills that will assist him in the redesigning of the suspension on the vehicle. Furthermore, this mechanical engineer has also the most contact with all the Mechanical Engineers on the team, so this will enable him to easily contact them without any issues.

One of the other Mechanical Engineers, Thomas Emerick, is another individual graduating this upcoming 2011 spring semester being a senior. He is managing the redesigning and replacing of the calipers within the brakes due to his experience with Mechanial Systems 1 & 2, and Dynamic Systems1 & 2. Subsequently, this course load has also given him the knowledge to complete the restoring of the body and shell on the vehicle.In addition, Thomas has exceptional ideas when it comes to designing the differerent mechanical engineering components of the vehicle.

The last Mechnical Engineer on the Formula Hybrid Project is Ryan Zombek. Ryan is a senior this school year and has had experience with various CAD packages, Thermal Fluid Systems and Mechanical Systems. On account of his practice with these courses, Ryan is the best team member qualified to achieve the redesigning of the suspension with Philip Young. Ryan will also be in charge of the rules and constraints of the Formula Hybrid Vehicle, as he was named the Rules and Safety Officer for the 2010-2011 year.

# Schedule



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#

#

# Gant Chart:

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# Milestone 1: Needs Requirements and Specifications

Milestone 2: Project Proposal and Proposal PowerPoint Presentation

Milestone 3: System Design Review Report and PowerPoint Presentation

Milestone 4: Detailed Design Review and Detailed Presentation

Milestone 5: Design Fair and Final Hardware Demo

Milestone 6: Final Oral Presentations and Competition

# 7 Budget Estimate

|  |  |  |  |
| --- | --- | --- | --- |
| **A: Engineers** | **Total Hours** | **Base Pay** | **Total Pay** |
| **Electrical/ Computer** |   |   |   |
| Lorenzo Neal  | 384 |  $ 30.00  |  $ 11,520.00  |
| Stephanie Medina  | 384 |  $ 30.00  |  $ 11,520.00  |
| IsrealDaramola | 384 |  $ 30.00  |  $ 11,520.00  |
|   |   |   |   |
| **Mechanical** |   |   |   |
| Phillip Young  | 384 |  $ 30.00  |  $ 11,520.00  |
| Thomas Emerick | 384 |  $ 30.00  |  $ 11,520.00  |
| Ryan Zombek | 384 |  $ 30.00  |  $ 11,520.00  |
|   |   |   |   |
| **Subtotal A** |   |   |  $ 69,120.00  |
| **B: Fringe Benefits**  |   | **29% of A** |  $ 20,044.80  |
| **C: Total Personnel Costs** |   | **A+B** |  $ 89,164.80  |
|   |   |   |   |
| **D. Expense** | **Quantity** | **Unit Price** | **Total Cost** |
| **i) Braking** |  |  |   |
| 2) Servo Unit | 1 |  $ 50.00  |  $ 50.00  |
| 3) Master Cylinder  | 1 |  $ 200.00  |  $ 200.00  |
| 4) Brake Lines | 4 |  $ 62.50  |  $ 250.00  |
| 5) Brake Hoses | 4 |  $ 25.00  |  $ 100.00  |
| 6) Brake Disks | 4 |  $ 62.50  |  $ 250.00  |
| **Subtotal** |   |   |  $ 850.00  |
|  |   |   |   |
| **ii) Chassis** |   |   |   |
| 2) Labor | 1 |  $ 1,300.00  |  $ 1,300.00  |
|  |   |   |   |
|  |   |   |   |
| **iv) Suspension** |   |   |   |
| 1) Spring/Dampers | 1 |  $ 1,000.00  |  $ 1,000.00  |
| 2) Heim Joints | 8 |  $ 10.00  |  $ 80.00  |
| 3) Steel (for control arms) | 30 |  $ 15.00  |  $ 450.00  |
| 4)Bellcranks | 4 |  $ 25.00  |  $ 100.00  |
| **Subtotal** |   |   |  $ 1,630.00  |
|  |   |   |   |
| **v) Fiberglass/Resin** | 1 |  $ 500.00  |  $ 500.00  |
|  |   |   |   |
|  |   |   |   |
| **vii) Charger** |   |   |   |
| 1) AC-DC Li-Ion Charger | 1 |  $ 550.00  |  $ 550.00  |
|  |   |   |   |
| **viii) Safety Equipment** |   |   |   |
| 1) Helmet | 1 |  $ 150.00  |  $ 150.00  |
| 2) 3-point harness | 1 |  $ 120.00  |  $ 120.00  |
| 3) ProFox Kit (suit, gloves, shoes) | 1 |  $ 350.00  |  $ 350.00  |
| 4) Hood | 1 |  $ 30.00  |  $ 30.00  |
| **Subtotal** |   |   |  $ 650.00  |
|  |   |   |   |
| **ix) Wheels** |   |   |   |
| Tires | 4 |  $ 100.00  |  $ 400.00  |
| Rims | 4 |  $ 100.00  |  $ 400.00  |
| **Subtotal** |   |   |  $ 800.00  |
|  |   |   |   |
| **x) Microcontroller** | 1 |  $ 250.00  |  $ 250.00  |
|  |   |   |   |
| **xi) Miscellaneous** | 1 |  $ 2,000.00  |  $ 2,000.00  |
|   |   |   |   |
| **xii) Travel** | 1 |  $ 5,000.00  |  $ 5,000.00  |
|  |   |   |   |
| **xiii) Registration** | 1 |  $ 1,500.00  |  $ 1,500.00  |
|   |   |   |   |
| **Subtotal of D** |   |  |  $ 15,030.00  |
|  |   |  |   |
| **E. Total Direct Costs** |   |  |  $ 104,194.80  |
|  |   |  |   |
| **F. Indirect Costs** |   |  **45% of E**  |  $ 46,887.00  |
|  |   |  |   |
| **Equipment** |   |  |   |
| **i) Internal Combustion Engine** |   |  |   |
| 1) Engine/Transmission | 1 |  $ 1,000.00  |  $ 1,000.00  |
| 2) Cooling System | 1 |  $ 150.00  |  $ 150.00  |
| 3) Exhaust System | 1 |  $ 300.00  |  $ 300.00  |
| **Subtotal** |   |   |  $ 1,450.00  |
|  |   |   |   |
| **ii) Electric Motor** |   |   |   |
| 1) Motor | 1 |  $ 1,200.00  |  $ 1,200.00  |
| 2) Motor Controller | 1 |  $ 550.00  |  $ 550.00  |
| **Subtotal** |   |   |  $ 1,750.00  |
|   |   |   |   |
| **iii) Chassis** |   |   |   |
| 1) Steel Stock | 1 |  $ 1,500.00  |  $ 1,500.00  |
| **Subtotal** |   |   |  $ 1,500.00  |
|  |   |   |   |
| **iv) Accumulator** |   |   |   |
| 1) Li-Ion Battery | 2 |  $ 1,125.00  |  $ 2,250.00  |
| 2) Housing  | 1 |  $ 75.00  |  $ 75.00  |
| **Subtotal** |  |  |  $ 2,325.00  |
|  |  |  |   |
| **G. Total OCO** |   |  |  $ 7,025.00  |
|  |   |  |   |
| **H. Total Project Costs** |   | **E+F+G** |  **$ 158,106.80**  |
|   |   |   |   |
| **I. Donated Parts** |   |  |   |
| Internal Combustion Engine |   |  $ 1,450.00  |   |
| Tires/rims  |   |  $ 800.00  |   |
| Microcontroller |   |  $ 250.00  |   |
| Chasis |   |  $ 1,300.00  |   |
| Charger |   |  $ 550.00  |   |
| Electric Motor  |   |  $ 1,750.00  |   |
| **Subtotal** |   |   |  $ 6,100.00  |
|  |   |   |   |
| **J. Overall Total Project Costs** |  | **E+F+G-I** |  **$ 152,006.00**  |

# 8 Deliverables

There were many objectives that were completed by last year’s team. This year there are still a large number of objectives that need to be completed in order for the 2011 FAMU-FSU Formula Hybrid car to compete and possibly win the overall competition. The first major and most important deliverable that must be completed this year is the incorporation of the internal combustion engine (ICE). This deliverable was chosen by the team to be the most important deliverable because in order for the car to be classified as a hybrid, it must consist of an electric motor and a liquid ran engine. In this case, the liquid ran engine will be an ICE from a Kawasaki motorcycle which was donated to last year‘s team. The second deliverable that must be completed will be redesigning of the suspension. The current suspension is very outdated so it will be replaced with new brakes, calipers, cambers, dampers, springs and other minor details. As of right now the hybrid car has only a single brake that acts on the differential, located on the back axel of the car.

According to the new rulebook, the car must have a single brake on each wheel. Therefore, in order for the car to pass inspection, it must consist of a single brake on each front wheel as well as each rear wheel. Sensors are another major deliverable that must be installed into the car this year. They are a neccessary part to the BMS to able to achieve the objectives required from it. More so this is where the use of current and voltage sensors comes in. Other sensors that have to be installed on the car include a speedometer, a sensor that measures the RPM, and if possible a gas level sensor. The primary sensors that must be implemented this year are current sensors and the speedometer. The third major deliverable that the team is not required to have but would like to implement into the vehicle is the incorporation of the Battery Management System (BMS).

The reason that this deliverable is important to Team 3 is because the batteries that are currently installed on the car are very expensive and hard to replace. So, the introduction of the BMS will allow all the batteries to be charged evenly without a single battery being overcharged. Overcharging can cause extreme damage to the vehicle and system. Furthermore, it can lead to the need of replacement, which we would like to prevent at all costs if possible.The BMS will also allow energy to be drained from the batteries evenly to prevent any single battery from being utilized more than the other. The uneven charging and use of batteries will cause that battery to wear out and become useless. Additionally, this BMS will also enable the car to be more energy efficient and it will prolong the battery lives. If time permits it, the team will also implement regenerative braking. To produce this deliverable, the team will force the electric motor to run backwards by charging the batteries. This can be done by re-programming the motor controller to tell the electric motor when to charge the batteries.

Other deliverables besides the vehicle deliverables mentioned include weekly minutes and documentation the Competition Committee will need. Details of these are listed in the Documentation Portion.

# References

[1] "Formula Hybrid Forums :: View Topic - Hybrid Powertrain Configurations." *Formula Hybrid*. SAE International IEEE, 26 Feb. 2008. Web. 13 Sept. 2010. <http://www.formula-hybrid.org/forums/viewtopic.php?t=160>

[2] Nice, Karim.  "How Differentials Work"  02 August 2000.  HowStuffWorks.com. 17 September 2010 <http://auto.howstuffworks.com/differential.htm>

# [3] SAE International. "2011 Formula Hybrid Rules." (2011): 1-124. Web. 24 Sept. 2010. <http://www.formula-hybrid.org/pdf/Formula-Hybrid-2011-Rules.pdf>

# 10 Appendices (Resumes)

**STEPHANIE MEDINA**

1325 West Tharpe St. #912 Tallahassee, FL 32303

**sm07h@fsu.edu**

(239) 398 – 0996

**OBJECTIVE:** Seeking to obtain a challenging internship position in the field of Computer Engineering and be a valuable asset to a company.

**EDUCATION:**

**Bachelors of Science in Computer Engineering December 2011**

College of Engineering; Florida State University; Tallahassee, FL

G.P.A: **3.08**

**SKILLS:**

* C++,Visual Basic, MATLAB, PSPICE, Exam DiffPro, Beyond Compare, Razor
* Microsoft Word, PowerPoint, Excel, Outlook
* Bilingual (Spanish)

**RELEVANT COURSES:**

* Senior Design1, Circuits 1-2, Electronics
* Object-Oriented Programming, Data Structures
* Microprocessors, FPLDS, Computer Architecture
* Signals & Systems, Communications, Statistical Topics in CPE/EE, Fields

**EXPERIENCE:**

**Senior Design (Formula Hybrid Car), Tallahassee, FL Program Manager/Lead Engineer August 2010 - April 2011**

* Lead team of six to compete in the 2011 Formula Hybrid International Competition
* Responsible for the implementation of the Battery Management System
* Program the Microcontroller for the coupling of the ICE with the electric motor

**Lockheed Martin MFC, Orlando, FL INROADS Software &Systems Intern May 2010 - August 2010**

* Designed and developed software solutions for 10 *JASSM Mission Planning* problems
* Performed testing to verify compliance of the system’s requirements for the JASSM missile
* Interfaced with various missile programs to gain a better understanding of daily operations
* Maintained communication with team members to accomplish assigned tasks
* Obtained a DoD Secret Security Clearance

**FAMU-FSU College of Engineering,Tallahassee, FL Undergraduate Research Assistant May 2009 - August 2009**

* Learned about different functions in MATLAB and applied them
* Created and wrote a program in MATLAB based on the Pattern Recognition System

**ACTIVITIES / AWARDS:**

* SHPE Conference/HENAAC Scholarship : Lockheed Martin recipient **August 2009 - Present**
* Hispanic College Fund Scholarship : Lockheed Martin recipient **August 2007 - Present**
* Society of Hispanic Professional Engineers : Outreach, Fundraising,

Corporate Sponsorship Chairs **September 2007 - Present**

* Phi Eta Sigma Honor Society : member **August 2009 - Present**
* Women in Math, Science and Engineering Program : member **August 2007 - Present**
* CARE Summer Bridge Program : member **June 2007 - Present**
* Bright Futures Scholarship recipient **May 2007 - Present**
* PEO Scholarship recipient **May 2007 - April 2009**
* Titan Way Scholarship recipient **May 2007 - April 2008**
* Naples Yacht Blue Gavel Scholarship recipient **May 2007 - April 2008**
* Scholars Club Scholarship recipient **May 2007 - April 2008**
* Golden Gate Women’s Club Scholarship recipient **May 2007 - April 2008**

Philip Young

12153 Monroe Street, Wellington, FL, 33414 • (561) 319-3985 •pay07@fsu.edu • U.S. Citizen

## OBJECTIVE:

To obtain a full time or internship position at a respectable engineering firm where my skills and knowledge of mechanical engineering can be utilized and challenged to further increase productivity and success of the company.

### EDUCATION:

Florida State University, Tallahassee, FL 08/2007-Present

### Bachelors of Science in Mechanical Engineering • Graduation: April 2011

### Overall GPA: 3.644, Engineering GPA: 3.615

Dean’s List - 5 Semesters

**Technical Elective Courses**: Design Using Finite Element Method, Vehicle Design (Graduate Level),

Gas Dynamics, Energy Conversion Systems for a Sustainable Future

**SENIOR DESIGN PROJECT:**

***Society of Automotive Engineers (SAE) Hybrid Formula Racer*** 08/2010-Present

FAMU-FSU College of Engineering; Tallahassee, FL

* Continue design and construction of a hybrid formula racer to participate in the nationwide SAE competition.
	+ Mechanical Engineering Team Lead
	+ Integrate and couple internal combustion engine with electric motor.
	+ Redesign and analyze vehicle suspension, braking system, and differential.

### EXPERIENCE:

***Teaching Assistant*** 09/2009-Present

Mechanical Engineering Help Center; FAMU-FSU College of Engineering; Tallahassee, FL

* Assist students with academics by explaining difficult topics, helping with coursework, and preparing them for exams and presentations in various mechanical engineering courses.

***Research Intern*** 05/2010-08/2010

Keuka Wind/Center for Advanced Power Systems**;** Interlachen, FL

* Collaborated with fabricators and machinists to develop various 3D models using Pro/ENGINEER including company construction barge, compressed air storage tank, and multi-blade wind turbine (U.S. Patent Number 7399162).
* Developed MathCAD spreadsheets to calculate drag forces on multiple wind turbine designs at various wind speeds and pressure forces on the inside of compressed air storage vessels.
* Employed calculated forces in Pro/MECHANICA to perform finite element analysis on created models in order to determine stress and deflection levels given various conditions.
* Produced various presentations on progress and presented these to supervisors and superiors.

***Research Volunteer*** 11/2009-05/2010

Scansorial and Terrestrial Robotics and Integrated Design Laboratory; FAMU-FSU College of Engineering

Tallahassee, FL

* Assisted in construction of iSprawl robot and Integrated Climbing Arboreal Robotic Ornithopter System (I.C.A.R.O.S.) project.
* Utilized Pro/ENGINEER to construct 3D computer models of robot components.
* Analyzed fluid flow over different wing designs to determine optimal design for performance.

**EXTRACURRICULAR ACTIVITIES:**

Society of Automotive Engineers, Member 08/2010-Present

Tau Beta Pi, Engineering Honor Society; Member 01/2009-Present

* Professor Recognition Committee; Coordinator 01/2010-5/2010

Pi Tau Sigma, Mechanical Engineering Honor Society; Member 08/2009-Present

* Fundraising Committee; Coordinator 08/2010-Present

**TECHNICAL SKILLS:**

Pro/ENGINEER, MathCAD, LabVIEW, MATLAB, CodeBlocks, CodeWarrior, Working Model 2D, Microsoft Office 2003/2007

*References available upon request.*

**Ryan M. Zombek**

913 Barrie Ave Tallahassee, Florida 32303 (561) 289-9391 rmz07@fsu.edu

## OBJECTIVE:

## Full time mechanical engineering position that will allow me to utilize the skills I haveaccumulated over the course of my college career. Open to relocate.

## SUMMARY:

* Mechanical Engineering internship with Teligent EMS Technologies in Havana Fl.
* Proficient with Office, CorelDraw, Mathlab, Comsol, Pro Engineering, MathCAD and Matlab.

## EDUCATION:

## Tallahassee Community College, Tallahassee FL

## AA Degree, General Transfer 2007.GPA 3.2 from Fall 2004-Summer 2007.

## Florida State University, College of Engineering, Tallahassee FLB.S. Mechanical Engineering with a Minor in Physics, April 2011.

*Relevant Courses*:

-Finite Element Analysis -Design of Fluid Thermal Systems

-Engineering Math -Mechanical Systems

-Material Science -Dynamic Systems

-Computer Programming -Computer Aided Design

 *Relevant Projects*:

* + Drafted, built and tested a stirling engine.
	+ Drafted, built and tested a basic solar heating system.
	+ Programmed, tested and ran a robot using Dragon-Board code in spring 2009.
	+ Design, built and competed a Hybrid Formula Racecar in the A.S.E competition in New Hampshire for my Senior Design Project.

*Educational Strong Points:*

* Finite element modeling 1D or 2D systems with or without Comsol.
* One or two dimension heat transfer with open or closed systems.
* Design of thermal fluid systems such as HVAC.
* Dynamics, Vibrations and Controls.
* Equations of motion for mechanical, electrical, and electromechanical systems.
* Statics, standard deviation and Optimal Design.

## EXPERIENCE:

**Teligent EMS Technologies (Havana, FL) 01/09 – 01/10**

### *Mechanical EngineeringInternship*

* Responsible for editing and insuring accuracy for the company’s Class 4 Military MPIs.
* Assisted with manufacturing Class 3 Military mechanical builds.
* Assisted with the design, procurement, and assembly for the department’s new manufacturing prep area.
* Head lead for printing all serial numbers on each of the company’s electronic circuit boards.

From the desk of

(850)766-5434 israel daramola iodaramola@gmail.com

2700 W. Pensacola st. Tallahassee, Florida 32304

# Education BACHELORS OF SCIENCE; ELECTRICAL ENGINEERING

## Florida State University; Tallahassee, FLMay 2011

Learned circuitry, computer programming, and completed an electric RC plane

# Experience OPS Research intern

## Florida A&M University; Tallahassee, FLJun2009-Present

Working with the computer program GENIE 3000, a gamma acquisition program that inspects spectroscopy data from medical patients; Making frequent trips to the Tallahassee Memorial Hospital facility in Quincy, Florida to complete this task; Researching gamma rays, their purpose and what they tell about the subject giving off these rays.

#  Cashier

## TEMOJ International; Tallahassee, FLAug 2005- May 2009

Working the cash register and answering the telephone for TEMOJ, an African clothing boutique. I would also fill in for the managers during emergency situations when they could not be at work.

#  Computer Research Student

## National Oceanic & Atmospheric Administration; Tallahassee, FLJan 2006- Aug 2007

Using computer programs to so research and studies on the environment and ocean life. I, along with a few other students also worked together on a presentation for the NOAA committee which earned us a higher pay raise.

#  SOFTWARE SKILLS

## Microsoft Works, Microsoft Office, Microsoft Publisher, Adobe Photoshop, Adobe Illustrator, C++, Binary Language

RELEVANT COURSES

Calculus 1,2,3; Physics 1,2; Chemistry; Engineering Math 1,2; Circuits 1,2; Electronics; Digital Logic Design; Signals and Systems; Communications; Thermodynamics; All-Electric Aircraft

LEADERSHIP EXPERIENCE

HISTORIAN

*PROGRESSIVE BLACK MEN, INC.*Jun 2009- Apr 2010 Revived a dying position within the organization, remade the the organization scrapbook and was rewarded with the Committee Of The Year award. PHOTOGRAPHER *SYNERGY* Jan 2010-current Helped organize the Synergy Unity Walk on FSU’s campus.

MENTOR *BSU FRESHMEN FIRST* Sept 2009- Apr 2010 Mentored first year students at FSU MENTOR *FAIRVIEW MIDDLE SCHOOL* Sept 2009 Helped kids with their homework or projects and studying for tests

|  |  |
| --- | --- |
| 2125 Jackson Bluff Rd. Apt J202 Tallahassee, FL 32304 | (803)553-3409 Neal\_Lorenzo@yahoo.com |

Lorenzo Neal

|  |  |
| --- | --- |
| Professional Profile | Seeking for an entry level position of electrical engineer where I can use my skills to develop my career. Able to display and video circuit designs. As well as to work independently and able to manage priorities and tasks. Excellent ability to express ideas.Able to build, customize and troubleshoot electrical designs. Excellent communication, organizational and interposal skills. |
| Experience | June 2010-present **Gate Petroleum** Tallahassee,FL**Cashier*** Two time employee of the month
* In charge of keeping an accurate cash drawer and safe
* Maintaining a clean and well kept store

May 2008-August 2009 **Picture Me Portrait Studio** Columbia, SCStudio Manager* Second place in regional sales average
* Managed 3 employees
* Maintained a profitable studio
 |
|  | October 2007-Janurary 2008 **Champs Sports Store** Tampa, FLStockroom Manager* Managed 2 employees
* Checking in new shipments
* Maintaining neat and well organized stockroom
 |
|  |  |
|  |  |
| Education | 2004-present Florida A&M University Tallahassee, FL* Electrical Engineering
 |
| Interests | IEEE, running, fishing, family, computers. |
| References | Available upon request  |

**Thomas Michael Emerick II**

tme06@fsu.edu

**Present Address Permanent Address**

306 Lipona Road 465 12th Place SE

Tallahassee, Fl 32304 Vero Beach, Fl 32962

(772) 633-7345 (772) 569-5153

**Objective**: Masters Degree in Mechanical Engineering

**EDUCATION**

 FLORIDA STATE UNIVERSITY, Tallahassee, Fl

 Major: Mechanical Engineering

 G.P.A : 3.37

 Dean’s List

 ASME Member

Sigma Alpha Lambda honor society member

**Interests**

* Aerodynamics
* Flow Visualization and Experimentation

**Computer skills**

* Pro Engineering, MathCad, MatLab, LabView, Programming in C

**WORK EXPERIENCE**

 **Florida Center for Advanced Air Propulsions** May 2010-Present

 *Fluid Flow Visualization*

* Develop techniques for shock shaping

**Eclipse Marketing** Summer 2008

 *Door to Door Sales Contractor*

* Collect payment, assist customer’s needs, schedule service dates
* Overcome rejection and fine tune communication skills