EML 4905 Senior Design Project

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PREPARED IN PARTIAL FULFILLMENT OF THE
REQUIREMENT FOR THE DEGREE OF
BACHELOR OF SCIENCE
IN
MECHANICAL ENGINEERING

SAE Formula Car – Dynamic Spoiler
25% of Final Report

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

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Abstract

!!!Work in progress- to be concluded once work done!!!

Introduction

A spoiler is a device designed to spoil turbulent air as it passes over the body of the vehicle. Some spoilers or wings are design to increase the grip or downward force that is applied to the vehicle. Our design is to have a dynamic wing, one that moves or adjust to the conditions that the vehicle faces as it accelerates and changes direction. A split dynamic spoiler allows for the downward forces generated to be applied to the wheels as they are need. This technology is being applied to high performance vehicles such as the Bugatti and Formula 1 race cars most notably the Red Bull team.

Problem Statement

The objective of this project is to design, build and install a dynamic spoiler for the Formula SAE race car team. FIU will compete in the Formula SAE competition that takes place in Michigan in the month of May. The competition events include an endurance race, acceleration, skid pad, design presentation, cost report and sales presentation. We will have to justify that our dynamic spoiler design will benefit the Formula race car in the endurance race and the acceleration and skid pad area of the competition. SAE club has asked our group to design our dynamic spoiler in such a way that it can be removable from the frame of the car. They also asked that we travel with the club to competition in Michigan and explain our design to the judges during the design presentation. SAE has a set of rules regarding the placement and size of wings that are placed on any race car. These rules will have to be satisfied before the race car can compete in any events, the list of applicable rules are in appendix A.

Motivation

A dynamic spoiler's goal is to increase the grip the vehicle has during turns and decrease the drag and add stability on the straights. Dynamic spoilers also aid in braking of the vehicle by increasing the surface area or drag coefficient of the vehicle. Currently Formula SAE race car groups do not implement dynamic spoilers and many SAE groups do not add spoilers in general. Florida international University SAE group wants to be the first group to bring this technology to competition. Not only would a dynamic spoiler help with the endurance race, it also aids the group in the design presentation.

Literature Survey

A spoiler is an aerodynamic device commonly used in racing. The main function is to 'spoil' unwanted air motion around the vehicle body, streamlining the air motion around the vehicle body reduces the amount of turbulence, therefore reducing the amount of drag and increase the performance of the vehicle. The other function that a spoiler has is to provide down force to the wheels that are transmitting the power from the engine. By doing this we increase the effective normal force acting on them without increasing the overall inertia of the vehicle, allowing it to turn faster since it has more grip but the same centrifugal force.

An active spoiler is an aerodynamic device that adapts its angle of attack depending on what conditions the vehicle is in. Its main purpose is still the same as that of a static spoiler, to increase the down force while spoiling unwanted air motion. However, since the spoiler can now adapt its position we can minimize the drag when driving on a straight line and maximize the down force when the car is braking. Not all competitions allow dynamic spoilers, for example in Formula 1 they have recently implemented a device known as DRS which stands for Drag Reduction System and essentially what this does is minimize the drag coefficient of the spoiler when the car is driving in a straight line by moving the bottom half of the spoiler to a horizontal position. This concept was first implemented in the Formula 1 world in 2011 to promote overtaking, and it is expected to offer the driver an additional 10-12 km/h when engaged [1]. As with any other Formula 1 technological implementation, there are new rules that come hand to hand with it, for example it can only be activated in certain specified sections of the track or when the car in front of you is a minimum of one second away [2]. Other teams such as RMR Rhys Millen Racing have developed conceptually similar devices to the Formula 1 DRS.

Our project differs from DRS in the sense that it will not be manually activated by the driver but instead it will be automatically controlled by an on board computer that will detect when the car is driving on a straight path and engage our system to reduce the drag force. This on board computer is an innovative application for this project since it will find the optimum ratio between drag coefficient and down force at all times.

Another big difference between the Formula 1 Drag Reduction System and our project is that the spoiler that we are developing consists of two independently moving wings as oppose to only one. Having two wings allows us a much broader spectrum of possibilities since now, not only can we increase the down force when braking and turning and decrease the drag when driving straight, but we can also distribute the down force to the tires that need it the most when turning. From our research we have found out that there is only one company that manufactures a wing with this concept and it is the S2 model from Aeromotions ™. [3]

Similar technology can also be found in other famous car manufacturers such as Bugatti; in their Veyron model they have implemented a dynamic spoiler that deploys when the car reaches 220 km/h providing an additional 350 kg of down force [4], this is done to increase the traction in the rear tires which are the ones carrying the power to the ground as the speed increases and the revolutions per minute of the rear tires also increase, allowing for a no slip condition to occur.

Design Alternatives

When deciding on different types of design, we first needed to focus on our main objective. We needed down force on the tires to create better traction on the floor, a static spoiler would have worked. With a static spoiler, we would not be able to control the amount of down force needed at specific areas of the race. To have control of the down force, we needed to create a dynamic spoiler. Having a spoiler able to shift its angle of attack during specific sections of a race would have an advantage in speed performance. With this in mind is how we started our design process, two main designs we thought up for a dynamic spoiler. One design was using a 3 pivot piston system, it would be mounted in the middle of the spoiler and be able to pivot in any axis. This proved a problem with stability and control of the amount of force wanted on each rear tire. Our second design was to have a two, 1 axis pivot system on the spoiler. The spoiler would be divided in half, one piston mounted in the middle of the left side spoiler and one piston mounted in the middle of the right side spoiler. This would give us more control of when we want the down force to be applied, which tire we would want it to apply, and with how much intensity we need to be applied.

Proposed Design

Our choice for our dynamic spoiler contains a bracket to hold the spoiler, pistons, springs, motherboard, pitot tube, etc. From *Figure 2 Flat Face Airfoil* to *Figure 23 Teardrop Airfoil 0 degree Incline* shows the types of airfoils we decided to test out for our spoiler. We will calculate which out of the three causes the least amount of drag with the most amount of down force.

Figure 1 Bracketshows a rough sketch in Solid Works of what we intend our mechanism to be. The mechanism that will hold the wings and tilt them forward will most likely be made of aluminum rods or carbon fiber, and it will consist of two assemblies as the one shown above. Each of the assemblies will be driven by an independent pneumatic piston which will be attached to the center bar, the actuator will have to be strong enough not only to lift the entire wing but to also hold it in place as the drag force pushes it down. When retracting the wing back to its original position, we were first considering to install a spring that will pull down, so that when the pneumatic actuator wasn't engaged it would automatically come back to its original position, there are three main reasons that we have chosen not to do this, the first reason is that by having a spring pulling down, the actuator would have to be able to hold not only the force due to the aerodynamic resistance of the wing but the additional spring, also it would be hard for us to control the speed at which the spring will retract the wing and this would potentially end up in damaging the mechanism, finally having only one actuator per wing will make the assembly, tuning and maintenance of the wing much easier.

The mechanism will later be mounted on a plane that we will have to adapt to the geometry of the car, since the car frame has not been built yet we cannot come up with the complete design of the mechanism, and we are forced to approach it in this manner.

The wings will most likely be screwed to the frame with through screws and nuts. We are currently still learning how to work with carbon fiber and we are realizing that punching or drilling holes in carbon fiber is a difficult task. Attempting to drill holes in carbon fiber results in separation of the fibers and weakening of the material in the local area.

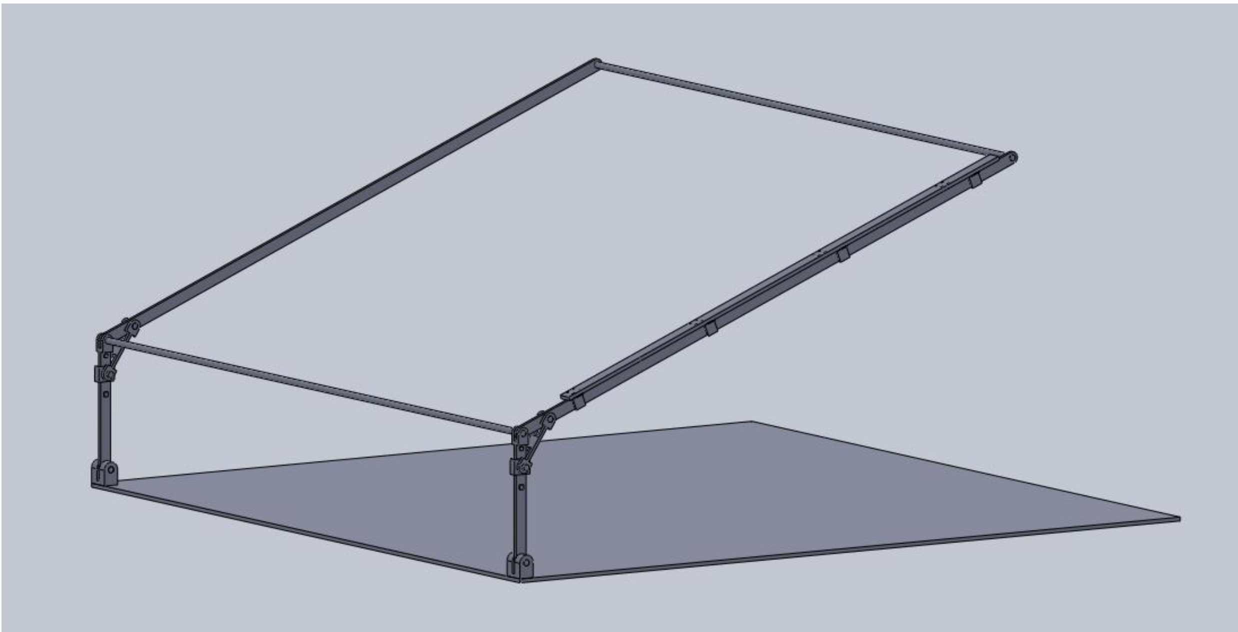

Figure 1 Bracket

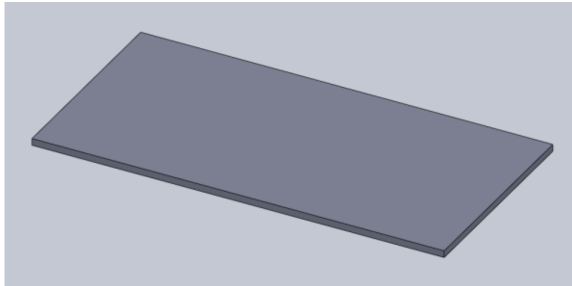

Figure 2 Flat Face Airfoil

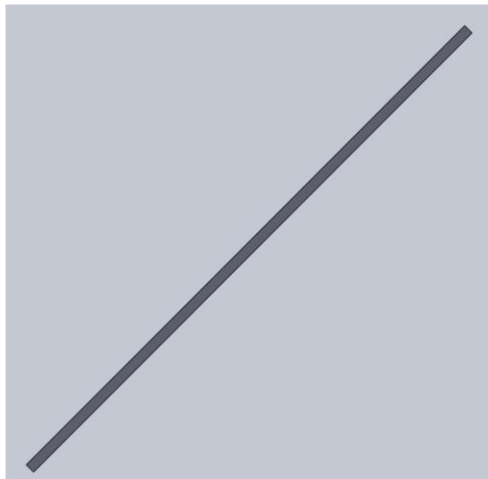

Figure 3 Flat Face Airfoil 45 degree Incline

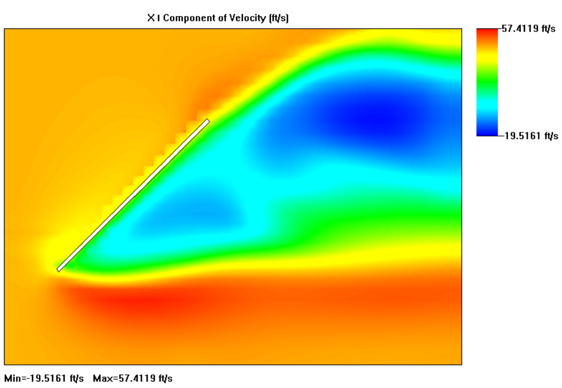

Figure 4 X component of velocity for Flat Face Airfoil 45 degree Incline

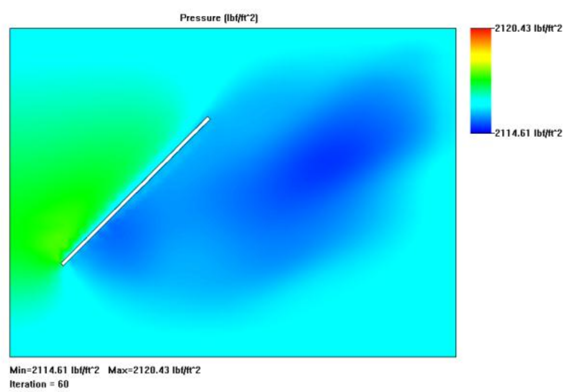

Figure 5 Pressure for Flat face Airfoil 45 degree Incline

Table 1 Numerical Data for flat face Airfoil 45 degree Incline

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
Av Total Pressure	[lbf/ft^2]	2118.4	2118.5	2118.4	2118.5
Av Velocity	[ft/s]	43.9	43.1	42.2	43.9
X Component of Force	[lbf]	1.1	0.9	0.8	1.1
Y Component of Force	[lbf]	-1.0	-0.8	-1.0	-0.7

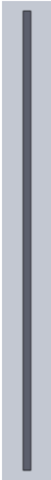

Figure 6 Flat face Airfoil 90 degree Incline

Figure 7 Flat Face Airfoil 0 degree Incline

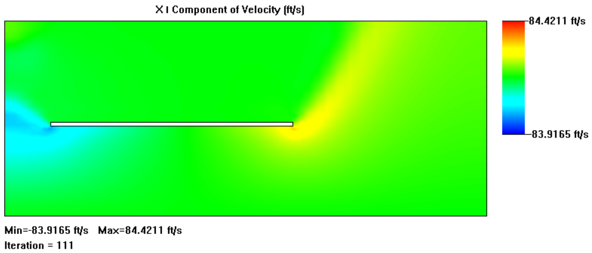

Figure 8 X component of velocity for Flat Face Airfoil 0 degree Incline

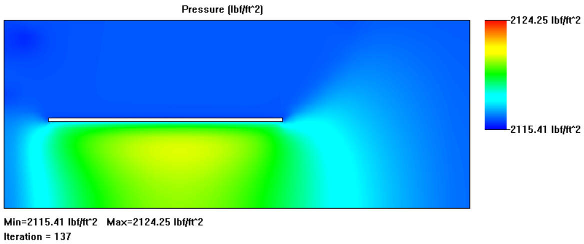

Figure 9 Pressure for Flat face Airfoil 0 degree Incline

Table 2 Numerical Data for flat face Airfoil 0 degree Incline

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
Av Total Pressure	[lbf/ft^2]	2119.3	2119.3	2119.3	2119.3
Av Velocity	[ft/s]	0.7	0.7	0.7	0.7
X Component of Force	[lbf]	0.0	0.0	0.0	0.0
Y Component of Force	[lbf]	3.1	3.1	3.1	3.1

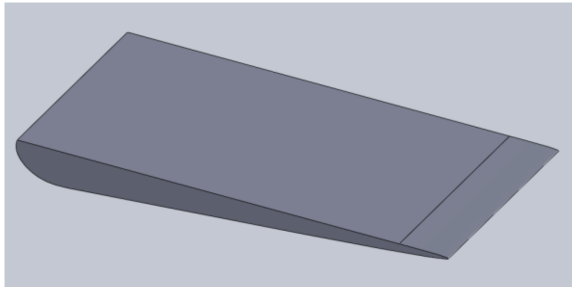

Figure 10 Half Teardrop Airfoil

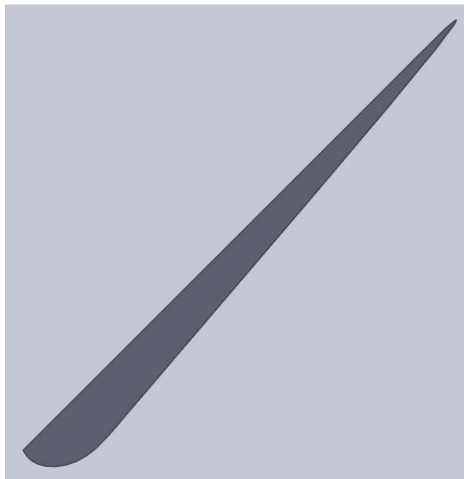

Figure 11 Half Teardrop Airfoil 45 degree Incline

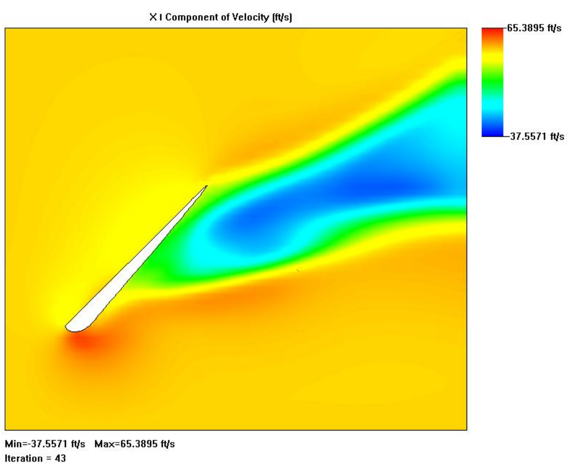

Figure 12 X Component of Velocity for Flat Top Airfoil 45 degree Incline

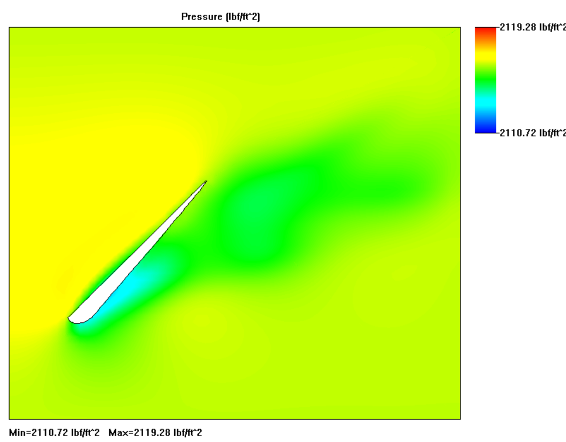

Figure 13 Pressure for flat top Airfoil 45 degree Incline

Table 3 Numerical data for flat Top Airfoil 45 degree Incline

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
Av Total Pressure	[lbf/ft^2]	2118.5	2118.5	2118.5	2118.8
Av Velocity	[ft/s]	44.1	44.1	44.0	44.4
X Component of Force	[lbf]	1.0	2.0	0.9	39.8
Y Component of Force	[lbf]	-1.1	-2.3	-36.5	-1.0

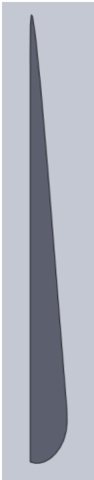

Figure 14 Half Teardrop Airfoil 90 degree Incline

Figure 15 Half Teardrop Airfoil 0 degree Incline

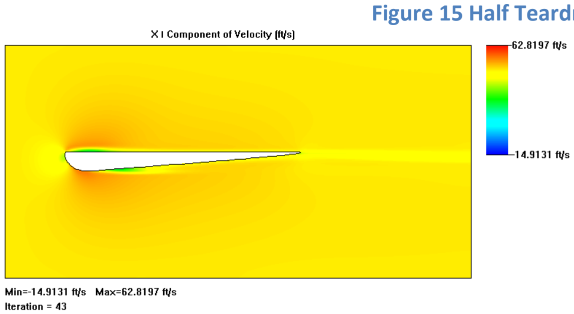

Figure 16 X Component of Velocity for Flat Top Airfoil 0 degree Incline

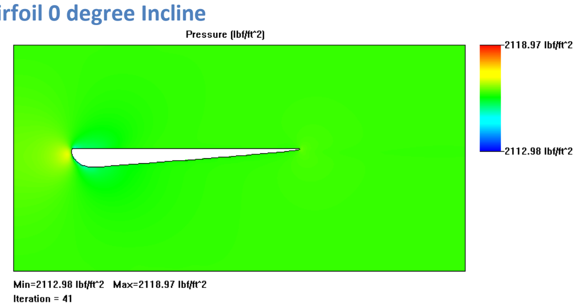

Figure 17 Pressure for flat top Airfoil 0 degree Incline

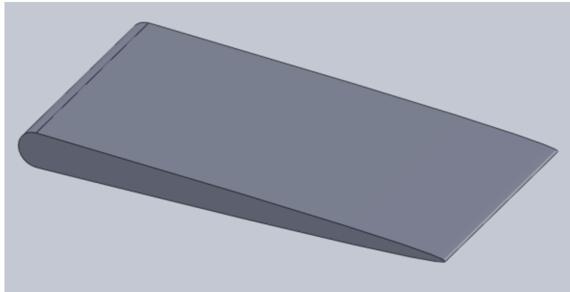

Figure 18 Teardrop Airfoil

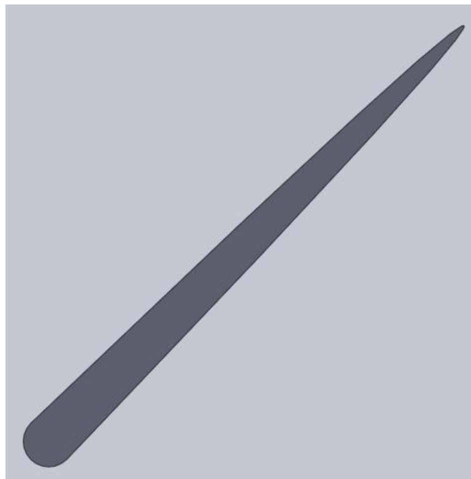

Figure 19 Teardrop Airfoil 45 degree Incline

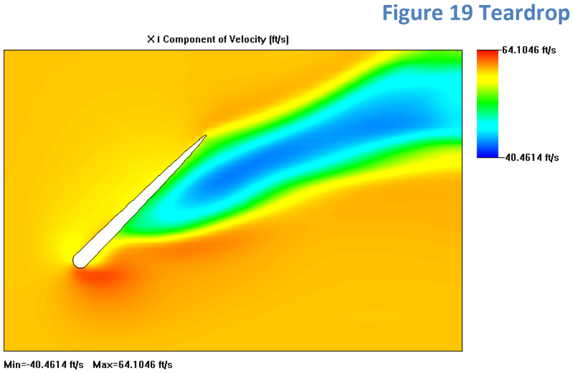

Figure 20 X Component of Velocity for Teardrop Airfoil 45 degree Incline

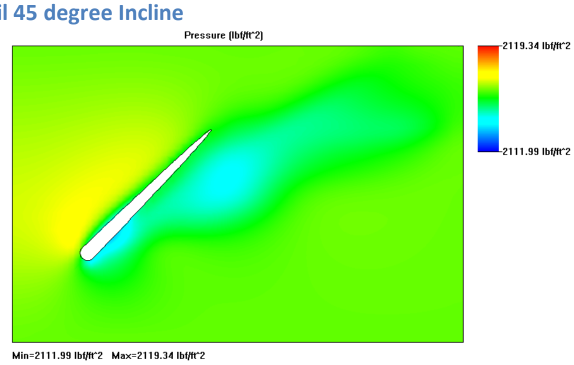

Figure 21 Pressure for Teardrop Airfoil 45 degree Incline

Table 4 Numerical Data for Teardrop Airfoil 45 degree Incline

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
Av Total Pressure	[lbf/ft^2]	2118.5	2118.5	2118.5	2118.6
Av Velocity	[ft/s]	44.0	44.0	43.9	44.2
X Component of Force	[lbf]	0.9	1.8	0.8	37.7
Y Component of Force	[lbf]	-0.9	-1.8	-36.6	-0.8

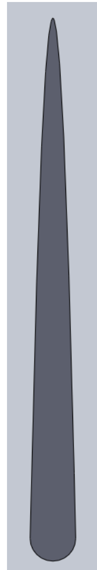

Figure 22 Teardrop Airfoil 90 degree Incline

Figure 23 Teardrop Airfoil 0 degree Incline

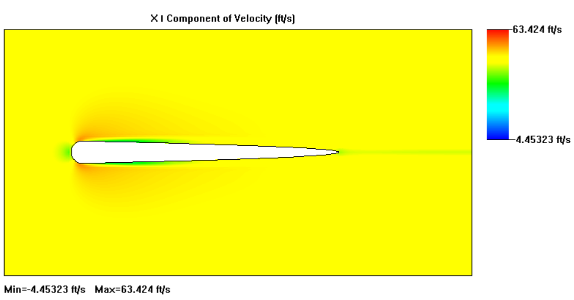

Figure 24 X Component of Velocity for Teardrop Airfoil 0 degree Incline

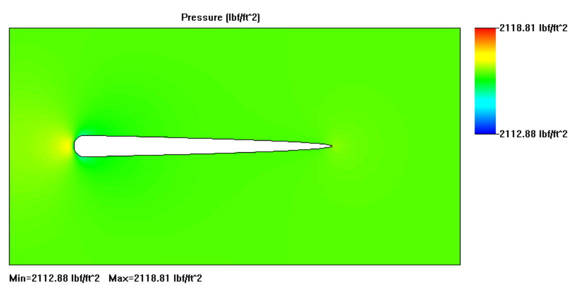

Figure 25 Pressure for Teardrop Airfoil 0 degree Incline

Table 5 Numerical Data for Teardrop Airfoil 0 degree Incline

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
Av Total Pressure	[lbf/ft^2]	2118.7	2118.6	2118.4	2118.7
Av Velocity	[ft/s]	45.6	45.2	45.0	45.6
X Component of Force	[lbf]	0.0	0.1	0.0	3.7
Y Component of Force	[lbf]	0.0	0.0	0.0	0.0

Timeline

Table 6 Timeline of senior project

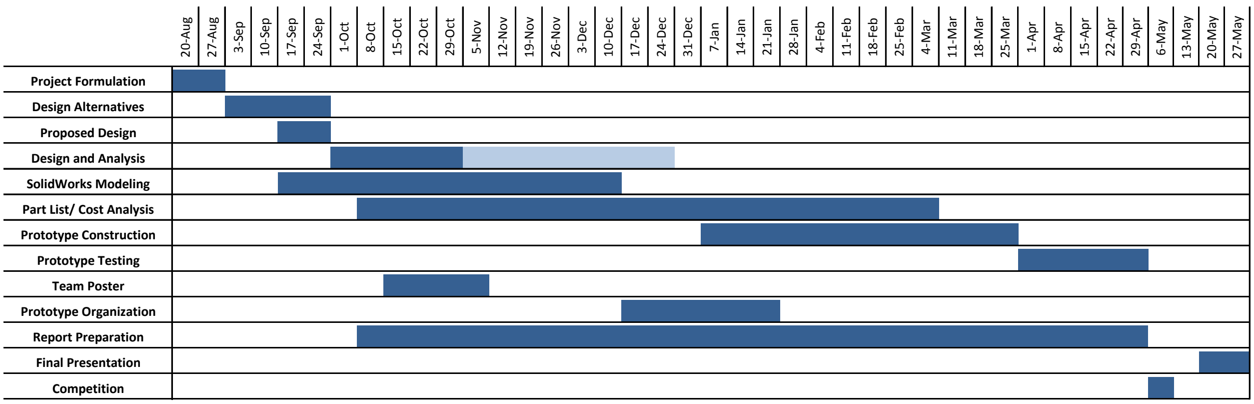

Table 7 Breakdown of responsibilities

	Project Formulation	Design Alternatives	Proposed Design	Design and Analysis	SolidWorks Modeling	Part List/ Cost Analysis	Prototype Construction	Prototype Testing	Prototype Organization	Report Preparation	
Adrian Ortuño Crespo	3	2	5	15	20	10	23	24	15	10	127
Brent Alexander Lougheed	2	1	3	13	15	19	23	24	17	10	127
Richard Pelaez	2	1	3	25	18	10	23	20	15	10	127
	Time in hours										381
											Total hours

Project Management

Engineering Design and Analysis

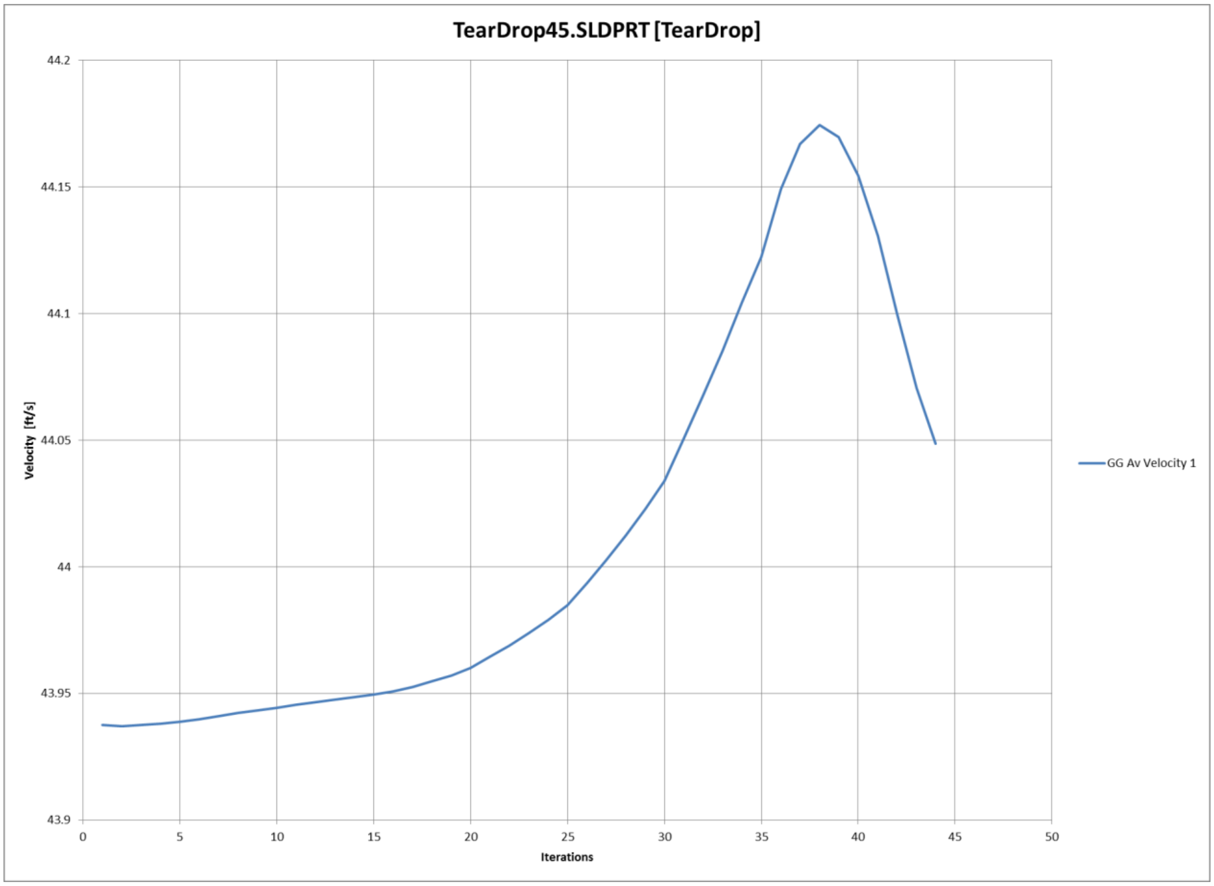

Figure 26 Velocity of Tear Drop Design

Table 8 Values for tear drop profiles

Goal Name	Unit	Value	Averaged Value	Minimum Value	Maximum Value
GG Av Total Pressure 1	[lbf/ft^2]	2118.4	2118.4	2118.4	2118.5
GG Av Velocity 1	[ft/s]	44.0	44.0	43.9	44.1
GG Av X - Component of Velocity 1	[ft/s]	42.7	43.5	42.7	43.8
GG X - Component of Force 1	[lbf]	0.866	1.81	0.755	37.7
GG Y - Component of Force 1	[lbf]	-0.898	-1.84	-36.6	-0.822

Table 9 Physics of a car

N_r	Normal force on the rear wheel
N_f	Normal force on the front wheel
F_r	Frictional force on the rear wheel

F_f	Frictional force on the front wheel
W	Gravitational force on Center of Mass
F_w	Drag resistance on Center of Mass

Table 10 Physics of a circle

Linear Velocity	v	$v = \frac{\omega}{r}$
Centripetal Force	F	$F = \frac{mv^2}{r}$

To start the analysis of required down force, understanding how forces acted on a vehicle needed to be understood. Once a vehicle starts to turn, the inside and outside radius of the turn are different. If both wheels would be turning at the same speed, the wheels will start slipping. To avoid slipping, the two wheels would need different velocities from the inside tire to the outside tire.

Major Components

Actuators

Figure 27 Actuators [17]

Purpose:

There will be two linear actuators which will be in charge of giving the motion to both wings. Linear actuators are more desirable than other motion providing systems for a couple of reasons. First of all since the driving parameter will be a linear displacement they are easier to program into the computer than other motion components. Also they meet the two most important requirements for our driving unit at a very reasonable price, they can withstand the loads that will come from the air resistance and they can move fast enough to keep up with the race.

Installation:

The linear actuators will be installed as follows. The bottom part of the actuator will be bolted to the main frame that holds the wing, the top part will be attached with a pin to the center-back of each wing. The power supply will come from a battery that will be placed under the wing and will be discussed later. The power will dictate the motion of the actuator, and it will be controlled by the computer.

Purchasing:

As of right now we are still looking into different types of actuators as well as different suppliers. It seems that the best option is to acquire electrically driven actuators instead of hydraulic or pneumatic. Not only they are cheaper but they are also easier to control since they only require a potential difference; also, they don't require a compressor which lowers the price and weight and increases the overall reliability of the system. We are focusing on two main parameters that the actuators must meet in order to be suitable for our design, the maximum vertical load and the maximum speed of engagement. [14][15][16]

Wings

Figure 28 Carbon Fiber Wing [18]

Purpose:

The purpose of the wings is to provide the braking force and the down force when engaged. We are looking into making them of carbon fiber because it is a light resistant material, ideal for racing purposes. The cross section of the wing will be analytically determined.

Manufacturing:

We are planning in manufacturing the wing ourselves, because this way we can dimension the wing according to the design requirements, performance specifications and SAE rules. We are still looking into the carbon fiber manufacturing process that we will be using, there will be a section explaining the process that we used.

Installation:

Each wing will be anchored in two different points in the front, this joints will most likely have ball bearings inside and will have a long shaft run through them, we are still perfecting this aspect of the design. In the back of the wing there will be one pin joint holding to the tip of the linear actuator that will drive the motion of the wing. Both wings will move about the same axis, which will be determined by the previously mentioned shaft.

Purchasing:

We are still looking for good local carbon fiber suppliers. Depending on what manufacturing process we decide is best for creating the wing we will need different materials, sheet thicknesses, etc. [19][20][21]

Control Unit

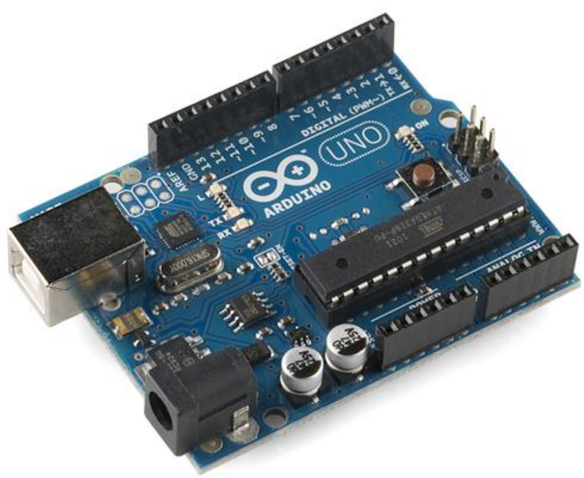

Figure 29 Control Unit [22]

Purpose:

The purpose of the wing is to provide the optimum combination of down force and drag at every possible situation that the car might find itself in during the race. In order to do this, a central processing unit is necessary; the computer will have a logic installed and three different inputs that will dictate what the position of the wings (output) will be. The three sensorial inputs are an accelerometer, a pitot tube and a turning sensor; they will be discussed in more detail later on.

Installation:

The computer needs a 12V DC power supply that will most likely come from the same battery that is powering the actuators. We will design a cage to fit it in in order to protect it from the hazardous environment that it might be subjected to during the race. The three inputs will be properly connected as well as the two outputs. Before installation the computer will be programmed with a logic that has been previously derived from our dynamic and aerodynamic studies of the vehicle.

Purchasing:

The device we have chosen to perform this task is the Arduino UNO. The reason for our decision is that this is an open source processor which means that there is a lot of global knowledge and external insight that will draw some light in the future programming and installation stages. Also, we purchased this device at a very affordable price, $22. [22]

Sensors

Figure 30 Sensors [23][24][25]

Purpose:

As previously mentioned, the computer will need three sensorial inputs to fully define the conditions that surround the dynamic and aerodynamic analysis of the vehicle. The three variables that we need are the speed of the vehicle, which will be obtained from the air velocity sensor or Pitot tube, the tilting of the vehicle and sideways acceleration, which will be given by the accelerometer and finally the rotation in degrees of the front wheels, which will be given by the steering sensor.

Installation:

The installation of these three components is still a subject that we are looking into. As Mechanical Engineers we did not get enough knowledge regarding computers and sensors so how we are going to install them is still the air. We know certain key factors though.

- Steering sensor: Will be attached to the steering column and will provide raw data of how many degrees it turns. We have to account for power steering in our calculations.
- Accelerometer: Will be installed as close as possible to the center of mass of the vehicle. We have to be careful to orient it the right way.
- Air velocity sensor: Will be installed in an open space where the flow is as laminar as possible. The opening will be positioned perpendicular to the direction of the air flow.
- Pressure sensor: It will be installed under the pistons that push the brake pads. It will be calibrated by applying different forces to the pedal, plotting the pressure values corresponding to those forces and coming up with a formula that represents that curve.

Purchasing:

There are many companies that sell sensors, but before we can choose one in particular we have to do a closer study of the inputs that we will need, the types of sensors that we will use and the accuracy we require for the data. [26][27][28]

Power Supply

Figure 31 Power Supply [29]

Purpose:

Most of the components that need electric power to function use direct current at twelve volts; this will be supplied either from a separate battery or the car battery. Also, one of the requisites that we have to meet is to make the wing as independent from the car as we can, this is why we will purchase a small rechargeable battery that will run all the components that require electric power. Also, it will act as a backup power source in case there are issues with the electric power coming from the car supply.

Installation:

The battery will be tightly attached to the center of the structure under the wing to avoid any eccentric forces acting on it that could result in unwanted vibrations. It will be directly connected to either the main battery in the car or the car electric generator.

A protective plastic or methacrylate cage will be created to house the battery in order to protect it from environmental factors.

Purchasing:

Currently we are not concerned about where to purchase this part as it is very commonly found in any automotive shop. When the time to choose it comes along we will be looking for a small battery, since we are going to give priority to the size and weight of the battery before its power storage. [30][31][32]

Frame

Figure 32 Material for Frame [33]

Purpose:

This frame will mainly serve two purposes. First of all it will add rigidity to the assembly, this is important because the forces that we intend to transmit from the wings to the ground could be somewhat high and they need a solid structure to be transmitted through. Also the wing has to be made removable and independent from the vehicle; for this reason we are forced to build it on a structure independent from the frame of the car.

Installation:

This is probably one of the most important and at the same time hardest installations that we will face. The reason being is that since this whole assembly is a different entity from the rest of the car, how we connect them together is crucial for the effectiveness of the wing as well as for its reliability.

We are still waiting to get the blueprint for the frame of the car, until we get it we can only describe in a very general way what we intend to do. Basically the main concern that arises when connecting these two bodies together is to make sure that there are no major stress concentrations in the connections since they could result in buckling, bending or breaking the components. We will need to perform a static analysis of forces from which we will determine what points in the main frame of the car are the best choices for applying forces and later we will have to design a frame that will hold the wing and will apply the forces in such a way.

Purchasing:

As with some other parts, purchasing of these components is not an issue that we are concerned with as of right now. Most likely we will make the frame out of aluminum or carbon fiber due to its low density and good strength. [34][35]

Other Mechanical Components

Figure 33 Mechanical Components [36][37][38]

Purpose:

The entire assembly will require of other minor mechanical components that we will be purchasing as we need, this might include pin joints, bearings, sliders, bolts and screws and more. These components are not listed as major due to their low cost, low importance when it comes to analysis and high availability. However it is very important to purchase high quality components that are rated for our application.

Installation:

Different components have specific ways of being installed, normally specified by the manufacturer, which we will have to rigorously stick to in order to ensure the overall integrity of the assembly. It is also important to analyze each of these components independently before approving them in the assembly.

Purchasing:

We will try and find a supplier that can provide most, if not all, of the components at a reasonable price. The reason we will try to purchase all parts from the same manufacturer is because they will come with a similar manual format, similar dimensions, and it is more likely to get a good deal. As of right now we still have not looked at this in much detail, however some possible companies are listed below. [39][40][41]

Other Electrical Components

Figure 34 Electrical Components [42][43]

Purpose:

In order to complete the circuitry of our system it is very likely that we need additional electronic and electrical components such as cables or resistors that we didn't mention. The purpose of these components goes from sending signals to supplying power or changing the voltage. As with the other mechanical components, it is important to purchase good quality parts for the correct purposes.

Installation:

We are still working on a complete schematic of the circuit that will include the sensors, CPU, battery etc… The installation of these components will be dictated by how we decide to put them together in paper first. It is important to pay special attention to each component to ensure that they are being used for the right purpose and in they work in the manner they were designed for.

Purchasing:

In a similar way as with the other mechanical components we will try and purchase all the electrical parts from the same supplier, in order to reduce costs and integrate all the parts of the design with more ease. Some of the designs we are considering are listed below. As we can see we will try to purchase the sensors and the rest of the electronic and electrical parts from the same companies. [44][45][46]

Structural Design

The spoiler is built for easy removal of from the Formula 1 car, this way; different spoilers can be used for different races on the Formula 1 car. In order to achieve this, we would need our design to hold everything needed in order for it to run on its own, independent of the car so testing can still be performed without the need of the Formula 1 car.

Our liner actuator will be powered by a separate 12V battery when it's being tested, but will have a separate connection to the Formula 1 cars battery for when it's mounted. Sensors will be installed in the structure to measure the acceleration and velocity of the system as well as have a separate connection in order to connect to the car when it's mounted on so it can receive data from the Formula 1 car itself. This will help us perform our test to the spoiler and then have easy access to mount it on the Formula 1 car when it's needed to race.

Cost Analysis

The cost analysis will be based on the material for the structure, components and materials for the airfoil that could be used for this dynamic spoiler design and prototype design. The analysis will be based on the cost of purchasing materials and components that are to be used for the design. Major components such as the material of the airfoil and the piston that will be used to adjust the angle of the spoiler will be focused on and compared to alternative options. The analysis of both aluminum and steel are considered for the structure of the dynamic spoiler.

The design team meets on Tuesdays and Thursdays, and occasionally on Sunday to formulate design and run simulations. SAE club mandatory meetings are held on Tuesday nights starting at 9:00 and ending at 11:00 every week. Each member spent on average 12 hours per week working on the project. The estimate total number of hours that will be required for the project is 381.

Prototype cost analysis

The prototype cost analysis will be based on the structure, components and materials needed for the dynamic spoiler. The analysis will compare multiple options for both the piston analysis and the material for the airfoil. The quotes of the components will come from online venders. This analysis will not include the operating cost of an oven or autoclave.

For the airfoil multiple materials were considered, factors that were important for choosing a material was strength and easy to shape or form. The first material considered for the airfoil was ABS plastic. Acrylonitrile butadiene styrene is a thermoplastic that has the ability to be shaped by injection mold. This would be an ideal material for the dynamic spoiler, since it is a typically material used for automotive body panels. ABS plastics are relatively inexpensive and common. US plastics [47] sell sheets of dimension 48" x 96" by 1/16" thick for $36.28. The problem with ABS plastics is forming the material; the typical method of forming ABS plastic is to use injection molding. Injection molding is an expensive method for forming one or two airfoils.

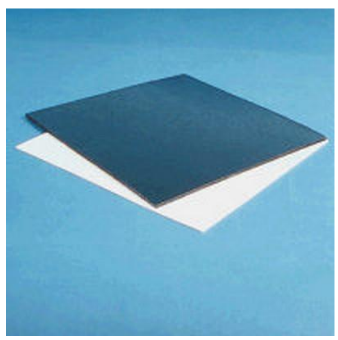

Figure 35 ABS Plastic Sheet Dimension 48" x 96" by 1/16" thick [47]

The second material considered for the airfoil was fiberglass. Fiberglass is a robust material most notable for its strength and lightweight. Fiberglass is very common in marine hulls and airplane wings and fuselage. A feasible method of forming or shaping fiberglass is to apply layers or sheets of fiberglass and lay resin over each layer. The fiberglass would then have to be baked in either an autoclave or oven. The cost for using fiberglass cloth would include the cost of the fiberglass, the resin and the safety material needed to apply the resin. According to fiberglass supply depot [48] for every yard of 50” 10oz cloth it takes about 1 quart of resin. Assuming that for each airfoil ten layers of fiberglass is need. The cost of a sheet fiberglass cloth 10oz with dimensions 10” x 60” is $2.99. Based on the dimensions for every two fiberglass cloth purchased one quart of resin will be needed Assuming that twenty sheets of fiberglass cloth is bought equaling $59.80 and 10 quarts of resin are needed to apply to the fiberglass. The cost of

1 gallon fiberglass resin according to auto body tool mart [49] is $59.99. This means that 3 gallons of resin is needed in order to sufficiently apply fiberglass to an airfoil mold. The cost of safety equipment that includes three 3M Maintenance Free Organic Vapor Half-Face piece Respirator one for each group member, tarps and gloves estimated at $100. The total amount needed to build an airfoil out of fiberglass would total $340. The total cost does not include ship cost.

Figure 36 Fiberglass Cloth 10oz. [48]

Figure 37 Polyester Resin Fiberglass Repair [49]

The third material considered for the airfoil was carbon fiber. Carbon fiber is most notably the strongest and the lightest material of the three. Carbon fiber is very common in the application of aerospace and Formula One. Similar to fiberglass carbon fiber can be layer over a mold or shape using resin between each layer. The material carbon fiber gains its strength from baking the layers and resin in an autoclave. Similar to fiberglass the cost of carbon fiber would have to include the material, the resin and the safety material used during the application of the resin. Unlike fiberglass, carbon fiber products can be cured using vacuum bags. This technique would allow an alternative method if an autoclave does not become available for the baking process. According to US composites [50] the cost for a sheet of carbon fiber with the dimensions of 5.7oz x 50” x 4 yards is $25.50/yard. The cost for the material of carbon fiber comes to around $102 for 4 yards of carbon fiber at that width and weight. If the same amount of resin is needed as for fiberglass, three gallons of resin would be needed. According to composite envision [51] the cost of one gallon polyester resin is $36.99. The total cost of the resin would be $111. The cost of the miscellaneous and safety equipment would equal about $100. The total cost of carbon fiber would be $313.

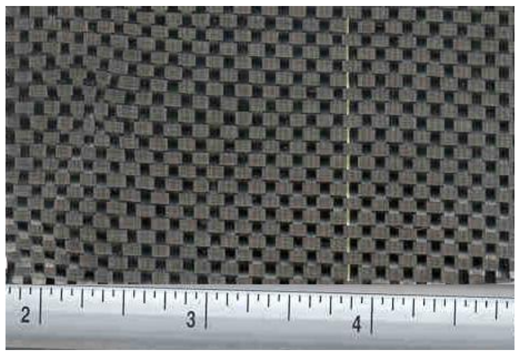

Figure 38 5.7 oz. Plain Weave Carbon Fiber 50” width [50]

Figure 39 Carbon Fiber Polyester Resin [51]

The major components that will analysis are the logic board and the pistons. They are the hardware that will move or adjust the angle of the spoiler. The logic board that has been purchased for the dynamic spoiler is Arduino UNO Figure 29. This logic board was purchased for its easy of programing and for the cost which was $21.95.

The two pistons that will be used to move the angle of the airfoil have to be compatible with the logic board, meet the force and speed requirement and be conservative on weight. Two types of piston have been analyzed, a pneumatic piston and linear actuator. The pneumatic piston will have the force requirement and will be compatible with the logic board. The cost of a pneumatic piston was quoted from allied electronic was $29.76. For two pistons the cost would be $60, mounting brackets and compressor are also needed. The problem with using pneumatic piston for the motion is the cost and weight of the accessories needed. Compressors, valve regulators, position sensors and pressure gages are needed. The weight of the components does not make pneumatic piston practical for a Formula race car.

Figure 40 Cylinder, Pneumatic, Front Nose Mount, 3/4IN. Bore, 6IN. Stroke, Magnetic Piston [52]

Linear actuators are light weight and can apply the required force and speed needed to achieve our goals for the dynamic spoiler. They require only an external power supply and the mounting brackets for installation. The cost of a linear actuator from Frigelli Automation was $ 129.99 each. For the dynamic spoiler the cost of the two linear actuators would be $260.

Figure 41 6" Stroke Tubular Actuator 150 lbs. force [53]

Depending on the parts and components chosen for the dynamic spoiler we estimate that the total cost of this project will be under $ 700.

Testing of Prototype

When gathering data for the spoiler, we have three main sources to gather information from. Using CFD analysis on our prototype will help us choose what size the wing should be to produce the amount of down force needed. Once the final design is complete, we will compare the analysis from Solid Works Flow Simulation and ANSYS CFD software for fluid flow, this data will then be used to calculate if it produces enough down force when needed.

Our physical prototype will be tested inside a wind tunnel in order to gather live data of how the spoiler dynamics act towards producing force. In the wind tunnel, the prototype will be mounted onto the back of the Formula 1 so the information gathered will include the air dynamics of the cars effect on the spoiler and also, the spoilers' effect on the car. The prototype will also be tested by mounting it on the Formula 1 car and taking it on a test run. This will show if our computations for the dynamic part of the spoiler was calculated correctly. Have the car run a lap with the dynamic spoiler will help us gather if the system as a whole is working together, we need the programming to calculate when to produce the force on either side of the car and we will need to make sure the right amount of down force is being produced.

Conclusion

!!!Work in progress- to be concluded once work done!!!

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Appendix

Appendix A: SAE RULE BOOK 2013

Location
In plain view, no part of any aerodynamic device, wing, under tray or splitter can be:

a. Further forward than 762mm (30inches) forward of the fronts of the front tires
b. No further rearward than 305mm (12 inches) rearward of the rear of the rear tires
c. No wider than the outside of the front tires or rear tires measured at the height of the hubs, whichever is wider.

Minimum Radii of edges of Aerodynamics Devices

All wing edges including wings, end plates, gurney flaps, wicker bills and under trays that could contact a pedestrian must have a minimum radius of 1.5 mm (.060 inch)

Ground Effect Devices
No power device may be used to move or remove air from under the vehicle except fans designed exclusively for cooling. Power ground effects are prohibited.

Driver Egress Requirements
All drivers must be able to exit to the side of the vehicle in no more than 5 seconds. Egress time begins with the driver in the fully seated position, hands in driving position on the connected steering wheel and wearing the required driver equipment. Egress time will stop when the driver has both feet on the pavement. The wing or wings must be mounted in such positions, and sturdily enough, that any accident is unlikely to deform the wings or their mountings in such a way to block the driver's egress.

Compressed Gas System and High Pressure Hydraulics
Compressed Gas Cylinders and Lines
Any system on the vehicle that uses a compressed gas as an actuating medium must comply with the following requirements:

a. Working Gas-The working gas must be nonflammable, e.g. air, nitrogen, carbon dioxide.

b. Cylinder Certification- The gas cylinder/tank must be of proprietary manufacture, designed and built for the pressure being used, certified by an accredited testing laboratory in the country of its origin, and labeled or stamped appropriately.
c. Pressure Regulation-The pressure regulator must be mounted directly onto the gas cylinder/tank.
d. Protection – The gas cylinder/tank and lines must be protected from rollover, collision from any direction, or damage resulting from the failure of rotating equipment.
e. Cylinder Location- The gas cylinder/tank and the pressure regulator must be located either rearward of the Main Roll Hoop and within the envelope defined by the Main Roll Hoop and the Frame (see T3.3), or in a structural side-pod. In either case it must be protected by structure that meets the requirements of T3.25 or T3.34. It must not be located in the cockpit.
f. Cylinder Mounting- The gas cylinder/tank must be securely mounted to the Frame, engine or transmission.
g. Cylinder Axis- The axis of the gas cylinder/tank must not point at the driver.
h. Insulation- The gas cylinder/tank must be insulated from any heat sources, e.g. the exhaust system.
i. Lines and Fittings- The gas lines and fittings must be appropriate for the maximum possible operating pressure of the system.