Drag Racing

Senior Design Final Report – April 2012

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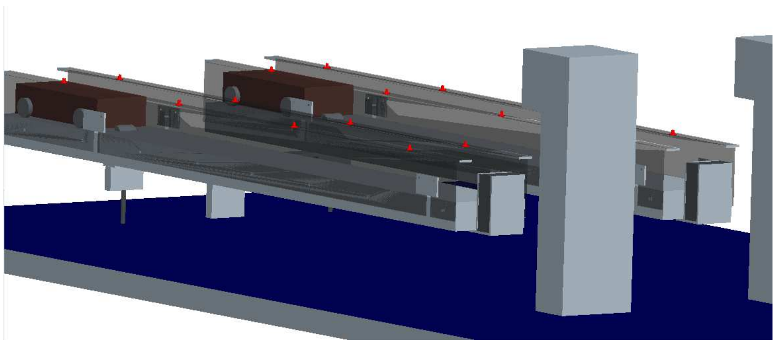

Project Sponsors
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Abstract

Team 13 is given the problem to modify an exsisting wind tunnel display. The final result should be simple enough to use so that no instruction is nessecary and long with being low maintenance, educational, and very robust. To tackle this problem the team brainstormed many ideas and finally selected on to go with, the drag race. In this concept a user will be able to select from a varity of shapes to race against eachother. The user will be able to launch the shapes chosen by a launch system that is spring loaded. The objective is that the user will select the one that will generate the least amount of drag therefore picking the winner. The winner will be shown by an electrical system that will be able to sense the winner and set of a light system. The user will also be able to see the velocity of the shape with an LCD display. The shapes that have met the qualifications are as follows, an airfoil, cube, bullet, and shell rod. Making sure that all the shapes have the same frontal areas will ensure that only the geometry of the shape plays a factor in the winner. Using aluminum for the shapes and easily obtainable electronical parts the overall cost the project will be kept very low. Making the shapes out of the aluminum will ensure that they do not break over excessive use however this will be a main safety concern. Being made out of solid aluminum means that the shapes are quite heavy therefore if they are dropped on a users foot it may cause damage.

1. Introduction

i) Project

Improving technology is one of the biggest concerns in today's economy. That's why there are a lot of investments in the area of technology. It is known that the best way to achieve this is by investing on youth minds. Today's youth will be our technology providers in the future. That's why investments in education are so important.

To develop interest in sciences and technology from children is necessary to make these subjects interesting for them. And one of the most attractive things for kids is a game. Create a game that teaches science and at the same time drags kids into an environment of fun is the best way to increase their interest on science subjects.

With this in mind, Dr. Shih and Dr. Oates of FAMU-FSU College of Engineering are head of an interactive project to claim the attention of children into the science field.

The project is now a Senior Design Project which Team 13 is responsible for to add features to the system. Focusing on the idea to grab the attention from children, Team 13 and advisors concluded to convert the wind tunnel and the tracks into a game, a drag race. This will show concepts of aerodynamics and physics, and at the same time, create an interactive environment for kids.

ii) Needs Assessment and Needs Statement

On this project we have the wind tunnel with the tracks and carts. We need to improve the system by adding some features, making it more interactive and attractive to children, and also trying to extract different physics concepts from these features.

iii) Project Description

Create an interactive game which teaches children basics concept of physics and aerodynamics, emphasizing drag force on different shapes, is the main goal of this project.

To achieve costumer's needs, we set some main objectives to guide the project:

	Objectives

1	Project must be easy to use
2	System must have a simple assembly
3	System must contain important technical concepts
4	Minimum maintenance needed
5	Concepts must be easy to understand
6	Automated system
7	Interactive interface

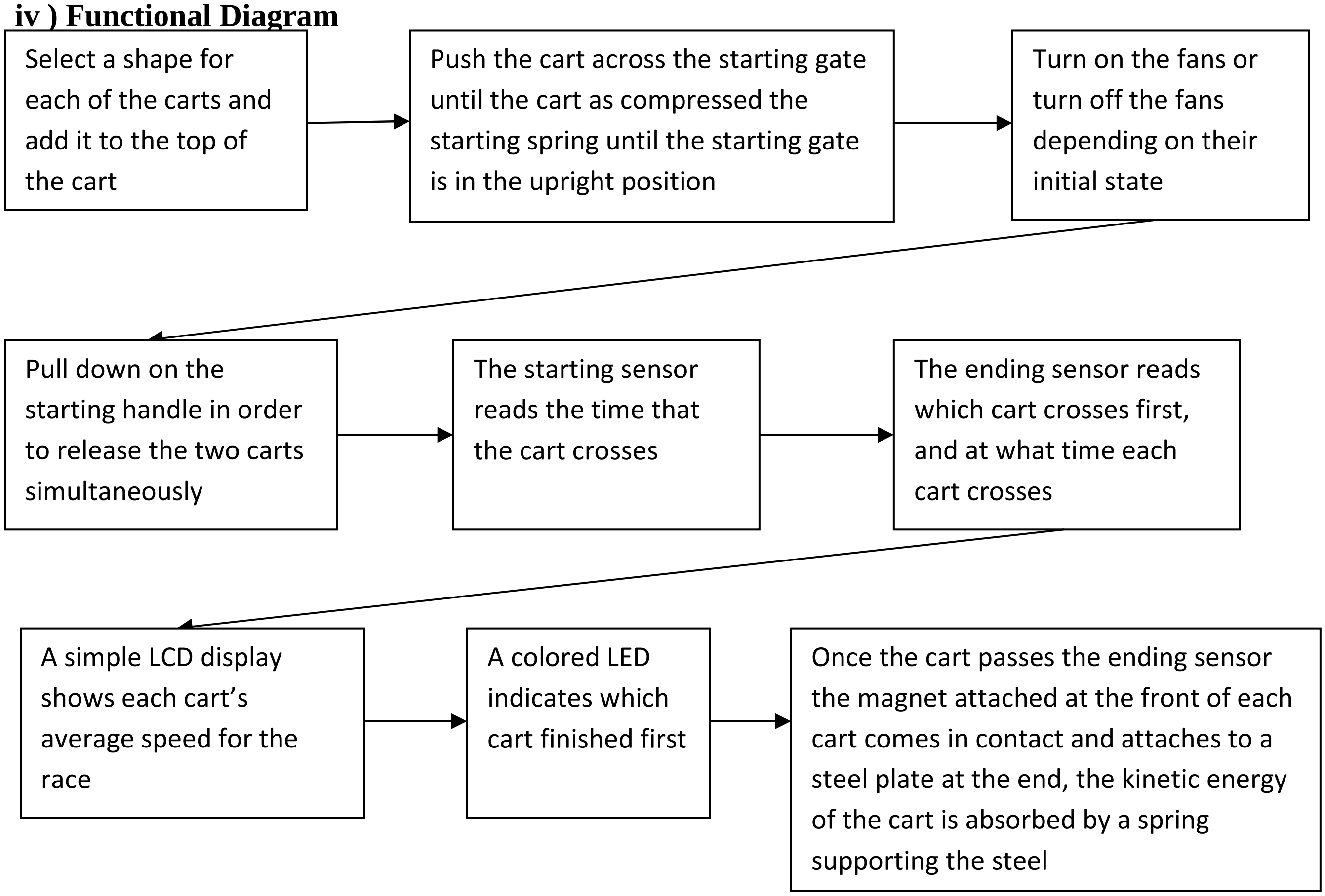
Table 1 - Objectives of Project

As the wind tunnel, tracks and carts were inside Dr. Oates Laboratory of Advanced Materials; this was our main place to build the project. This is where assembly process happened. Most of our parts were manufactured in the Machine Shop located at FAMU-FSU College of Engineering. We also used the Mechatronics Laboratory to solder the electrical components, to create the code that goes inside the board that controls our system, and to test the electrical system.

Our project does not have too many constraints. Actually, as one of our objectives is to create an interactive and attractive display, this kind of need demands few restrictions as we have to be creative to implement attractive features. However, as the project is mainly for kids, we need to care about their safety. That's why this project doesn't allow kids to select air speed by interacting direct to the fans. They can only turn on or off the fans. Also kids will not be able to take the carts off the tracks.

Time was also a constraint for us. We needed to finish the project until at the end of spring semester. However, we had been delayed on our materials order and we had to design the project all over again because our first costumer, the Mary Brogan Museum of Arts and Science, was closed. So this cause a delayed on construction process.

iv) Functional Diagram



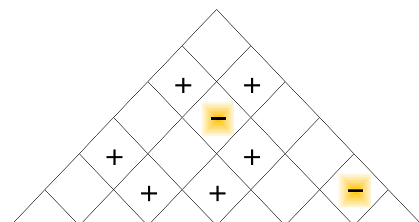
v) Quality Function Deployment

QFD: House of Quality
Project: Drag Race

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼



Row #	Weight Chart	Relative Weight	Customer Importance	Maximum Relationship	Customer Requirements (Explicit and Implicit) / Functional Requirements	Safety	Interactive interface	Automated system	Easy to assemble	Easy to use	How well concept is introduced	Our Product
					Column #	1	2	3	4	5	6	
					Direction of Improvement	◇	▲	▼	◇	◇	▲	
1		33%	4	9	Attractiveness to children	○	●			○	○	5
2		42%	5	9	Number of Concepts Introduced		○	●		▽	●	3
3		25%	3	9	Minimum Maintenance	○		●	●	●		2

Technical Assesment	1	2	3	4	5	6
Target	.	.	.	.	.	.
Maximum Relationship	3	9	9	9	9	9
Technical Importance Rating	175	425	600	225	366,67	475
Relative Weight	8%	19%	26%	10%	16%	21%
Weight Chart						
Our Product	3	5	3	4	3	5
Column #	1	2	3	4	5	6

Figure 1 - House of Quality

vi) Project Plan

Based on the schedule from Senior Design Course, we planned to complete the design process on fall semester. For spring semester we have planned to review all the design process, and start and finish construction process. Design process consist in develop ideas for the project, research for concepts that will help on design process, choose the best idea based on concepts acquired, improve chosen idea and plan its fabrication process. Fabrication process includes all steps to take the idea out of papers and make it real. From select parts, order them to assembly process and test the system, these are all on the fabrication plan.

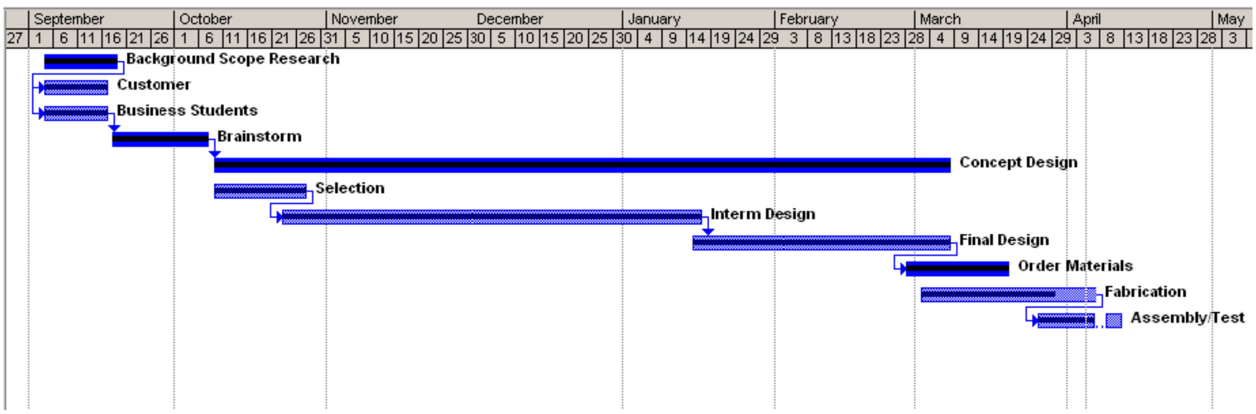


Figure 2 - Gantt Chart

2. Concept Generation and Analysis

Concept 1 - Airfoil

A staple in visualization of air flow is airfoils; they are used in most wind tunnels to show different pressure regions as the angle of attack changes. For our wind tunnel it is no different, our team will use a simple wind design attached to a rotatable pin which is also contained within a sliding mechanism. The rotatable pin allows for the user to change the pitch angle so that different wakes and pressure differences may be experienced. The sliding mechanism allows for the airfoil to rise and fall as the pitch angle is changed so that the user is able to see the different lift forces that are applied with the different pitch angles. The only issues is since the flow isn't laminar the airfoil has to be adjusted to mostly turbulent flow. This concept allows for a lot of user interactions with the possibilities to adjust the pitch, it also is a very simple concept when it comes to doing air flow. Another benefit is the low maintenance cost of the idea, because there isn't anything that needs to be up kept. An issue with concept is the lack of streamlines that can't be shown so that different wakes due to different pitch angles can't be shown. Also the airfoil isn't going to be switched with another one so there is no variety in using the airfoil; as always space in the air box is also an issue.

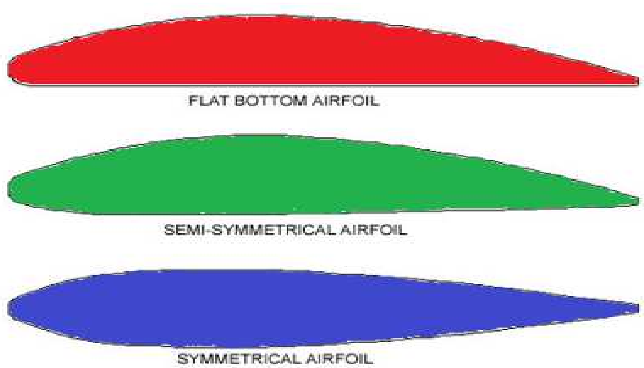


Figure 3 - Various Airfoil Designs

Analysis

The concept of the airfoil is meant to give us a simple but effective way to peak the interest of young minds. Its choice was mainly based on a need to draw in the attention of a young mind as well as demonstrate the scientific evaluation of air flow that we desire. With the presence of a wing it is our goal to associate a scientific lesson or principle in a way that anyone will be able to relate to it, or easily understand it. Lift is a simple idea that most people can grasp, and giving people a wing in a control volume that they can control the lift with a simple input is a great way to integrate higher learning with reap world applications.

Concept 2 - Carts

For this concept our team will supply multiple different attachments that are able to be placed on traditional carts to interact with the air flow. The carts will be stationary on the track with an airfoil or different geometric shape (circle, square, or a triangle) attached to the top of the cart so as the fans generate more flow the carts will be able to move and increase in speed based on the attachment used. This concept allows for a lot of interactive play with kids of all ages as well as helps the user understand which shapes can cause more drag and thus causing the cart to move faster. The concept gives a good visualization for drag forces but is unable to actually display the flow of the air. The concept is also very cost efficient in that it only requires few pieces to be implement. A big issue with this idea is that the user would actually need access to the wind tunnel so that could cause some safety issues if someone could have access to the wind tunnel.

Figure 4 - Cart used in Wind Tunnel

Analysis

The carts are a generally simple idea, and when working with kids the simpler the better. The carts are a good way of displaying drag effects on an object, by showing the force as displacement of the carts, making the learning experience visual. The attachments would be easy to machine out of any material because they are the simple shapes of a sphere and a cube. The attachments would be providing most of the drag force, while the tower and the cart would provide some; the majority of the drag would be from the attachment. The implementation of the carts would be relatively easy, just placing it behind the airfoil experiment and while the airfoil is not in use the carts can be played with. Although there is some use of visuals with the displacement of the cart, an accompanying COMSOL with the carts would be necessary. The COMSOL would be able to help visualize the actual fluid flow over the attachments, not just the forces. The user needs to be able to see how the fluids movement over the system to see how the forces of drag and lift are created. The cart is going to be one of the feature experiments in the wind tunnel because of its simplicity and ability to teach.

Concept 3 - Hand

A different concept compared to actually using an airfoil is to allow access to the wind tunnel and have a user use their hand in place of an airfoil. The air box can have an opening that allows for the user to place their hand into the experimental area and the user then specifies the speed to which they want to flow to act at and uses their hand to feel the different drag and lift forces. The benefit of allowing the user to actually put their hand in the air box is that it lets their hand feel the different forces acting on their hand rather than being told the forces acting on an air foil. The hand concept allows for a tactile response to the forces within the air box, the user feels the change in lift and drag as they change the angle of their hand. The hand idea is also very cost effective in that our team don't need to purchase anything from a third party, all that is necessary is just making modification to the air box. The issue again is safety, if the user is allowed within the air box it could cause technical issues if they decided to touch or move things that are supposed to be. Another rising issue is that the fluid flow isn't actually visualized again, it is only felt.

Figure 5 - Hand Acting as Airfoil

Analysis

The use of the users hand inside of the of the wind tunnel allows for the user to be able to experience the lift and the drag produced by the air flow instead of being told by the display the forces that are achieved from the air flow. The use of the users hand will be able to increase the interactivity of display by allowing the users to feel all the forces as well as play in the air flow. The issues with the hand are that the users will be able to have access to the wind tunnel and because the projected audience of the wind tunnel is k-12, the users cannot be trusted to stay within the guide lines. Most children tend to be mischievous so allowing a child access to the wind tunnel will only result in more issues then learning. The hand will be under further review because of the safety concern with access to the wind tunnel.

Concept 4 - Smoke

Concept 4 uses the idea of smoke in order to expose the airflow lines around the different bodies present in the wind tunnel. Out of all the possible ways of showing the flow and fluid mechanics' phenomena, smoke is the easiest to mount and has a very clear visualization. Air flow tracers would be positioned in front of the blowers so thin lines of smoke would be produced along the air's path. Since the smoke is easily visualized, the changes in the air's behavior due to different bodies' dimensions and aspects could be seen and understood. Another advantage of this concept is that only the tracer's handles need to be in the wind tunnel, the vaporizer could be positioned in the compartment below the tunnel so it would not occupy a lot of space and also would not require big changes in the actual configuration of the tunnel.

Furthermore, this project aims to be attractive and fun for kids to use and learn so the smoke would catch their attention for being something that is not commonly seen and for the different behaviors that smoke will have around the objects. Especially in the airfoil case, the attack angle can be changed which will allow the user to play with it and observe the changes caused because of that variation.

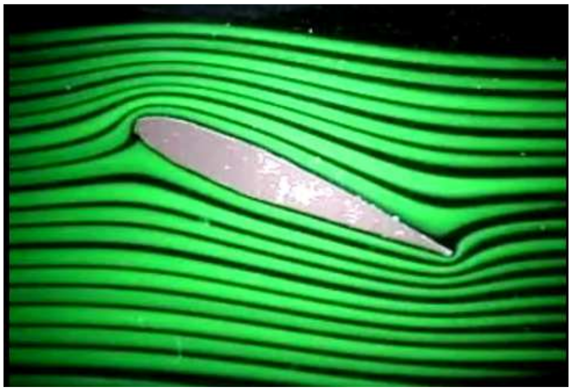


Figure 6 - Flow lines around body.

Figure 7 - Air flow tracer

Analysis

This concept has its strong points based on the ease of seeing flow visualization and in the attractiveness that the use of smoke will have at kid's attention. Also, this concept does not require big changes in the actual wind tunnel design since only the tracer's handle needs to be positioned in front of the blower. Two major issues in this concept are the maintenance and cost due to the constant oil replacement needed because of the vaporizer's high oil consumption. The vaporizer's tank has autonomy of only 9 hours and the oil replacement's cost ranges from $30 to $40. Although the smoke helps in the visualization, there is a problem with the smoke coming out of the tank. An exhauster or some gas absorber would have to be placed in the other side of the tunnel so the smoke would not get to the museum's environment. Together with this, since the tank cannot have big dimensions due to the space available at the museum, would be hard to create a laminar flow in order to have straight smoke lines for visualization what ends up eliminating the idea of using this concept.

Concept 5 - Wake Visualization

The concept of a wake is hard to display without any smoke or lasers so a possible way to allow for wake visualization is to use an actuator and place it behind the airfoil, or what whichever device is creating a wake, and once the turbulent flow vibrates the metal beam the frequency is found and from there a voltage is produced. From that voltage we can display it on the led screens and show that there is a wake created behind the air foil. The concept is able to show the users that an actual wake is created behind different objects, as well as slows for an interactive component with the wakes. An issue with the concept is the space it will take up in our air box might cause issues with other types of visualizations that are going on. The actuator also requires electrical connections which might be an issue within the air box. Without test the actuator our team is unsure if the frequency produced will be significant enough to produce a usable voltage

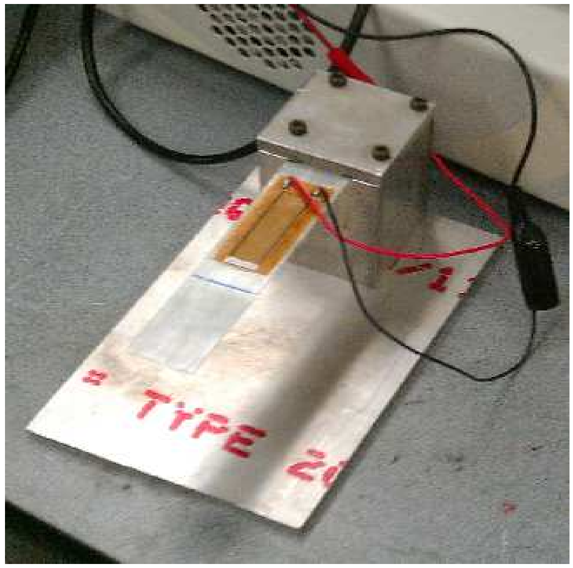


Figure 8 - Wake Actuator

Analysis

This concept is extremely low maintenance. Once installed, it will be capable to run under its own power. This means that other than a quick check to make sure that it is still functioning properly not much more would be necessary. When attached to LEDs, this display may be useable for young viewers. The number of LEDs to light up would indicate the intensity of the wake behind the object. However, due to the limited space inside of the wind tunnel this idea may not be possible. Depending on the number of LEDs that would attached, the larger the voltage that would be required to turn them on. Because of the space constraints this idea will not be implemented at this time.

Concept 6 – Drag Racing

For the this drag racing concept will included using verious shapes that from which the users can select two and race them against eachother. The shapes shall all produce a different amount of drag which will designate the winner. Having fans blow wind against the shapes will provide for enough wind that only certain shapes shall reach the finish while others do not. This will show to the user that different geometric shapes result in different drag forces even though the frontal area is the same from shape to shape. A major issue with this is in finding a sutable launching system and a coresponding system to indicate the winner. Another problem will come with the manufacturing of the shapes themselves.

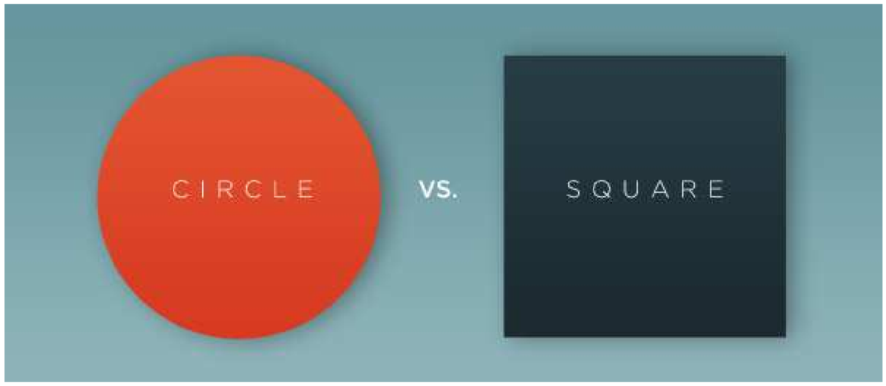


Figure 9 - Comparison of Square and Circle

Analysis

This concept is highly interactive. The user will be able to select the shapes that he/she will want to put against eachother. They will also be able to decide whether or not to have the fans running. The shapes themseleves can turn out to be very good attention grabbers which will entise a younger audience to use the wind tunnel to learn about fluid dynamics. The selection of the shapes can also add to a competition type feeling with the race where one user picks and shape and another selects a different and the winner will set of the alarm. The alarm will hopefully bring in more people to use the wind tunnel.

3. Concept Selection

		Cost	Maintenance	Space	Robust	Edu.	Simple	Safety	Total
	Weight	0.1	0.25	0.1	0.1	0.25	0.15	0.05	10
Phase 1									
	Air Box	10	9	10	10	7	10	8	8.9
	Towing Tank	1	7	2	8	10	8	5	6.8
Phase 2									
	Smoke	3	1	4	9	10	9	7	6.1
	Cart	8	8	8	7	7	9	9	7.9
	Hand	10	10	8	10	6	10	2	8.4
	Airfoil	6	9	6	8	9	7	8	8
	Actuator	8	9	7	8	5	5	8	7
	Drag Racing	6	10	10	9	8	7	4	8.25
	10=good	1=bad							

Table 2 - Concept Selection Table

The decision matrix above takes into account all the specifications that are deemed necessary to this project. The first was the cost of implementing each idea. The sponsor does not want to spend a large sum of money therefore; simple inexpensive visualizations should be used. Another major point is that the display should require little to no maintenance. If at all possible keep the maintenance to an annual checkup. Since the wind tunnel is already built the space for the devices is limited. The main point of this project is for it to get used repeatedly by people so being robust must be considered. The display must also be able to teach the user the concept that is trying to be presented. Finally, keeping the wind tunnel simple and not over complicating anything and safe are the final criteria. The matrix itself is a two phase matrix. The first phase was to decide between the towing tank or stay with the current design. The second are the various ideas to demonstrate different flow characteristics.

The final decision that we have decided to go with is the drag racing. This concept will allow for maximum user interaction along with an educational experience. Although there is a possibiliy for complications with the manufacturing of the shapes and with the launching system however the oppurtunity that goes with the user interaction and how simple the whole system will be once completed outweigh this complications.

4. Final Concept – Drag Racing

For electrical system it was necessary to attend main objectives demanded by the project. As this is a project that wants to show concepts of physics and aerodynamics, main focus was on show electrical concepts to the users. However, electrical concepts were really helpful to make the system more interactive, autonomous and safe.

With that in mind, it was decided to use some LED's to make system more attractive, IR sensors to measure velocity of each cart and show them on a LCD display, and relays were used so kids will not be allowed to mess with fans.

Along tracks LED's were added in two different colors: blue for one track and red for the other one. When the system starts LED's are on, so the players can choose between who will be the "blue player" and "red player". Before and during the race the LED's are on, however when first cart achieve end of the track its LED start to blink and the other track has its LED's off. This is how winner is displayed.

With LED's chosen a circuit was built so the LED's could work. LED's are like diodes, so they don't have a linear behavior between current and voltage. Different from a resistor can't use regular linear equations to predict current that will pass through LED's when it is submitted to certain voltage. Graph below show this difference between resistor and LED.

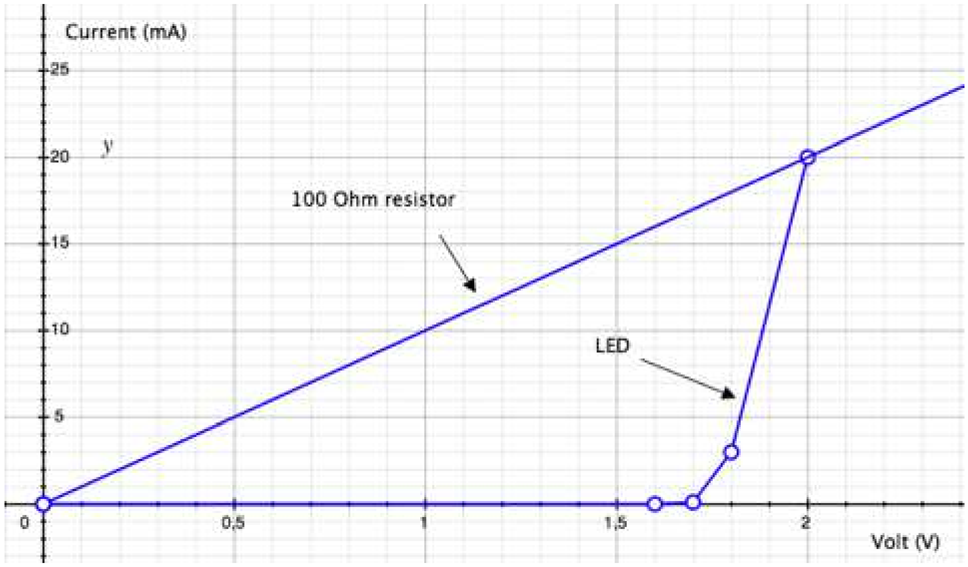


Figure 10 - Graph of Resistor vs. LED

So as LED can be very sensible to small oscillations in the voltage, need to connect a resistor to the LED so it will not die if this happens. For High Intensity Blue LED, consulting its datasheet, values for their maximum forward voltage and maximum forward current can be obtained, which are going to be used to select appropriate resistor. The same can be found for Bright Red LED. On the table below, found all these values can be found and the different resistor that for each LED.

	Max. Forward Current [mA]	**Max. Forward Voltage [V]**	**Resistor (R1) [ohm]**
Blue LED	30	4.5	62
Red LED	30	2.5	150

Table 3 - Resistors for LED

LED's were connected in parallel so resistors and LED's will be submitted to the same supply voltage. Supply voltage is provided by the board that we are using. In case of this project, Dragon Board provides 5 V. On figure below there is the circuit used to the LED's.

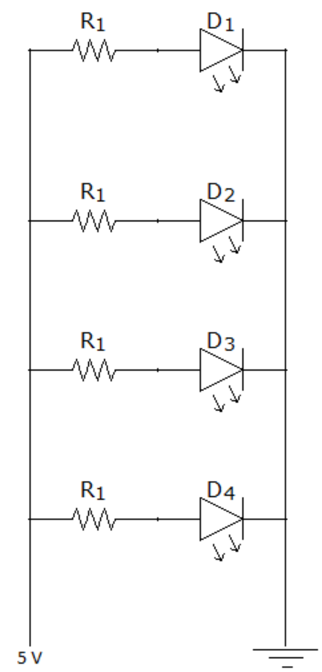


Figure 11 - LED Circuit

IR sensors were attached to the two tracks so speed of two carts can be measured. First a sensor on the very beginning of the track. So when cart passes through it a signal is send to microcontroller that will start to count time. Another IR sensor will be located close to the end of the track, so when cart passes through this one another signal will be send to microcontroller. Now the board will take the time and the distance between two sensors and calculate the mean speed of the cart. The speed will be displayed on LCD connected to the board.

The IR sensors will also be responsible to determine which cart was the winner. When cart cross last sensor, and signal were sent to the board, board will check if this is the first signal received from last IR sensors and if it is, it will send a command to LED's, so they can blink. As the winner is already known, board will automatically send a command for the looser track, so LED's will turn off.

For the IR sensors an IR Photo Emitter/Transmitter and an IR Photo Receiver were used. But to use them we had to build a circuit to support them.

The transmitter works as a diode, so to select the resistor for it same knowledge showed for LED's was used. However, to protect the IR Emitter a resistor was used based on the maximum power specification founded on the Emitter datasheet. Using equation 1 resistance value can be figured out:

$$\frac{Vcc^2}{R_1} < Power_{specification} \quad (1)$$

Resistor must be connected in series to act like a voltage divider. That’s how it will limit voltage through the diode.

For the Photo Transistor circuit, responsible to receive the signal from IR Emitter, resistor were connected in series. It is necessary to send a different signal when the transistor is detecting regular light from the environment and when it’s detecting IR light. Through some researches with figure out resistance should be between 10kohms and 11kohms.

Circuit will also have a signal wire which will be responsible to send to the board voltage value when receiver captures IR light and when it doesn’t. If receiver isn’t capturing IR light signal wire value is close to 5 V, which is the supply voltage. When light is captured, voltage value is under 2V. The figure below shows electric circuit for IR sensors.

Figure 12 - Sensor Circuit

To increase the safety of our system, fans were set with the desired speed, so the kids are not allowed to change it. They will only interact with the fans by turning them on or off.

To make this happen relays were added to the fans. But to implement the relays a circuit had to be built which will support them, making them works. Circuit is showed below.

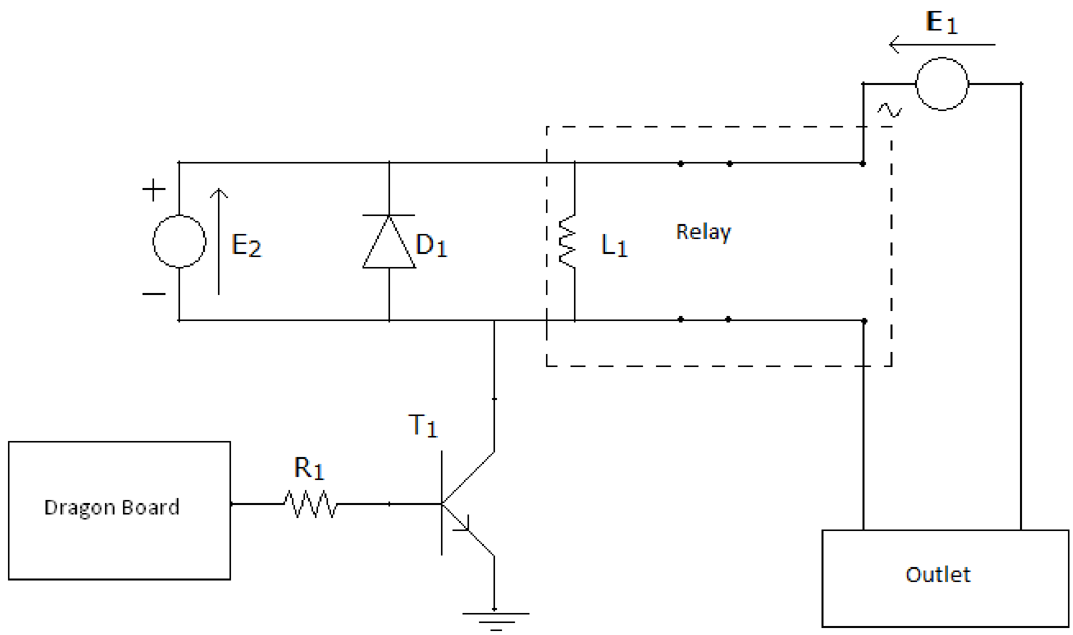


Figure 13 - Relay Circuit

Where E1 is the wall supply.

Relay is a switch which is operated electrically. So to the relay work a power supply is needed which will feed the coil inside the relay. Power supply depends on the relay that is being used, in this case a 12 V power supply, represented by E2. As E2 are giving power to the coil, essential to ensure that the power stored by the coil doesn’t go toward our board. That’s reason for the diode D1. It will make sure that the power flow will keep between power supply and the coil of the relay.

A signal from the dragon board to the relay, to actually turn on or off the fans, a transistor to connect and manager the current between dragon board and relay. Transistor that was selected was a NPN, to switch on when current that came through diode is high. If it’s low use a PNP transistor (See figures below).

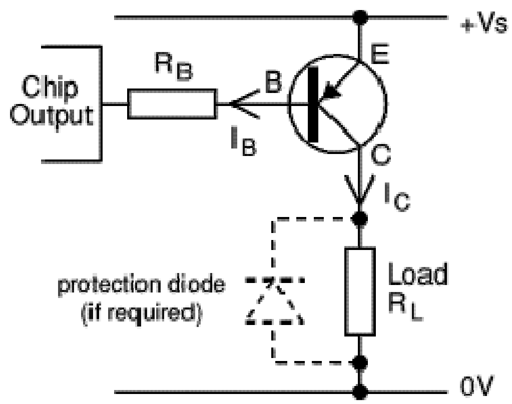


Figure 14 - PNP Transistor

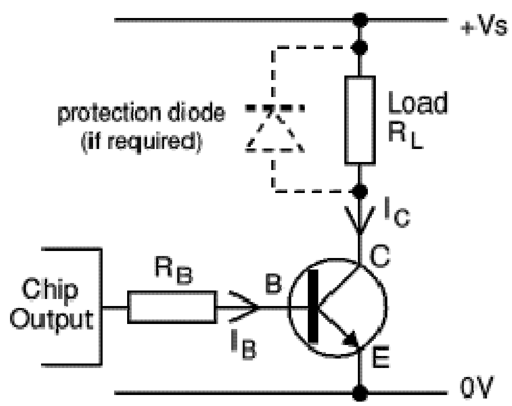


Figure 15 - NPN Transistor

To choose the NPN transistor that best fits into the design, two basic variables were considered: Load current (IC) and minimum current gain (hfe). To calculate them using following equations:

$$IC = \frac{supply\ voltage\ Vs}{Load\ resistance\ Rl} \quad (2)$$

$$hfe\ > 5 * \frac{IC}{IC_{max}} \quad (3)$$

Minimum current gain should be greater than five times IC divided by maximum output current. With these two parameter the transistor can be chosen, and calculate R1 value (resistance to limitate current between transistor and board). For R1 calculation use equation below:

$$R1 = \frac{V_s * hef}{5 * IC} \quad (4)$$

The outlet included into the circuit it’s where the fans are connected. Include them on the system, so it won’t be necessary to damage the fan’s wires, striping them, for example.

For the selection of the shapes, we wanted to have a very large difference in the drags. This would allow for maximum differences in the distances traveled by each of them. In order to select the shapes we referred to Fundamentals of Thermal-fluid Sciences. From this we concluded that the best possible shapes to use would be a cube, shell rod, airfoil, and bullet. No only do these shapes have different drag forces but they also are vary greatly in appearance. This will allow a user to be able to visualize that the geometric shape does play a large role in the drag force that is produced.

The airfoil is a general wing shape made out of solid aluminum that is 5”x1.25” on the frontal face. This was made in a CNC machine to ensure that it would be smooth and allow the airflow to not separate until intended. This shape has the lowest drag coefficient out of all of the shapes which means that it will reach the end before all of shapes.

The bullet is shaped as an enlarged bullet that has a semi sphere as a nose with a 2.8” radius. It also is made out of solid aluminum made in a CNC machine. The bullet has the second smallest drag coefficient which means that it should be able to follow the airfoil in second place for a race but beat the other two shapes.

The cube is solid aluminum cube with a 2.5”x2.5” frontal face. This shape has the second highest drag coefficient and should only be able to be the shell in a race. The shell is an aluminum tube that was cut in half that is 4”x1.56”. The cup portion will be facing into the wind which will give the shape the largest drag coefficient and should always lose the race.

All of the shapes and mounted to an aluminum base and standing on an aluminum rod that is 3.5” tall. This will ensure that any drag that is experienced by the these parts will be uniform for all shapes once again leaving only the geometric shape to be the deciding factor of the winner of a race. To attach all the pieces, thread the ends of the rod and drill and tap a hole in all the shapes and base plates. Once this is done to ensure that none of the shapes are facing a direction that is not desirable, glue the shapes and base plates in place.

Based on operational requirements of this display it was necessary to design and implement many support structures and governing mechanisms. Such important systems include guard and support railings to the main tracks used for the display, a starting and a stopping mechanism, and modifications to the base materials made available for this display. These additions needed to be robust and safe for use by a wide age range of customers; this important characteristic is what drove the major design points of each section.

The Starting mechanism needed to fulfill a few roles, first and foremost it needed to enable simple and have repeatable setup as well as be intuitive to the observer; it as important that the overall design be simple and easy to repair as the display should be low maintenance; finally the starting mechanism needs to be independent across both tracks, it is important that both carts can be setup independent of each other.

To execute these important design criteria it was first necessary to determine the impulse which would drive the carts across the track. The most simple method being a spring in compression, this would allow simple repeatable system starts as long the compression lengths of both carts are the same. To ensure that these lengths would be the same two independent gates would rise up from beneath the track and block the carts progress in one direction. These gates would be spring loaded and could be removed together through simple a handle, but reset independently.

It is also necessary to control the stopping of both carts as it is desirable for the total display to have a controlled response, carts rebounding back and forth across the track after runs is not ideal. To achieve a one direction propulsion across the track magnets are attached to the front of the carts, and steel plates await the cart at the finish line. To mitigate the impact force and reduce the chance of the magnet not staying attached to the steel an elastic section is added between the steel plate and the finish line support.

It was also necessary to design support structures for the infrared sensors, light emitting diodes, and to keep the carts secure and separate from any observers. To meet all three of these requirements at once plexiglass railings are fitted to the sides of the track. These railings cover the top section of the track enough that the cart can not be removed from the track, but shapes can still be loaded and removed from each respective cart. The side sections of these railings have slots removed which allow the infrared sensors to be mounted at the critical locations for monitoring the start and end of the display. The top sections of the railing support the colored LEDs which are used to indicate which cart crossed the finish line first.

All components used to start, stop, and secure the carts and major track features will be secured by either screws or strong adhesives when weights allow. This allows for easy of construction and the use of smaller surfaces when appropriate. It is important that the finishing support plate be steel as a ferris metal is necessary for magnetic attraction, the starting components are aluminum to assist in basic strength and ease of manufacturing.

5. Engineering Economics

The mechanical engineering department along with the senior design professors set the maximum budget for the project to be $2,000. The budget for the project is sponsored by the mechanical engineering department at the FAMU-FSU College of Engineering under the supervision of Dr. William Oates and Dr. Chiang Shih

Below is a list of all the purchases made by Team 13

Item	Quality	Cost per unit($)
Aluminum bars	5	39.31-88.24
Paint	1	21.97
Paint Supplies	1	9.97
Gorilla Glue	2	10.97
Wall Outlet	1	2.99
Light Switch	1	8.97
Washers	24	0.11
Screws	2	0.98
Plexiglass	1	50.00
Aluminum rod	1	50.00
Steel Bar	1	50.00
Springs	3	50.00
Electric system	1	76.00

Total Cost	559.04 $

Table 4 - Cost of Materials

The Aluminum bars and the Gorilla Glue were used in the creation of the shapes; the aluminum was used to create the stands, rods, and the shapes themselves. The Gorilla Glue was used to ensure that everything stayed connected between the rods, shapes, and stands. The Gorilla Glue was also chosen because it was cost effective and was similar to expoy. The reason that aluminum was purchased over other materials is because it was the most cost effective material for the durability. The paint supplies and paint were purchased so that the housing could have a new appealing color (Gem Turquoise) so that the users would want to interact with the display. The washers and screws were purchased to edit the track and make sure that the track is held in place properly. The purchases of the wall outlet and the light switch were for the exterior operation of the fans from the user. The light switch is durable and big so that the user can see it and it will be able to withstand multiple uses.

The aluminum rod, steel bar, and springs were all used to create the starting mechanism and housing for the cart to be placed in when the drag race has started. The plexiglass was chosen for the housing because it keeps the cart on the track, while allowing for the user to still be able to see the cart in motion. The aluminum rod was chosen because it was cost effective and durable, while the steel was chosen because it will become magnetized when in contact with a ferromagnetic material which is necessary for the stopping mechanism The electric system was purchased so that the user will know the speed at which the cart is traveling and have a LCD to display it.

6. Results and Discussion

Electrical System Analysis

To confirm all calculations made on design process, like resistors for LED's, resistor for relay system, transistor for relay system, and sensors configuration, some tests were made to check if all these systems were working and their reliability.

For LED's, as their conection could be wrong, or during solder process and when they were manipulated, something could happen to damage circuit, so they were connected to the Dragon Board and a 5 V signal were sent. This showed that LEDs were working as they supposed to do.

For the sensors, they were connected to the Dragon Board. So voltage was measured on the signal wire while cart was passed through the sensor. Observing that voltage varied during the process, this means that sensor were working, as it was recognizing that something had passes through it.

To test if the relay system was working, a 12 V voltage was applied, and a click could be heared when the relay starts to switch on and off. Every time voltage was applied, it switched on. When voltage was cut off, relay switched off.

Even that all electrical systems are not connected together on the Dragon Board, tests showed above can confirm that individual systems are working. Next steps are to put everything together and connected to the Dragon Board.

Air Flow Analysis

The most important step when determining the dimensions and materials of the shapes and there assembly is the air speed provided by the air blowers. Due to the nature of these blowers the airflow provided varies in both speed as the distance from the exit nozzle increases and distribution vertically as well. In order to achieve an accurate measurement of the airspeed at specific locations a pitot-static tube was used. Using the dynamic pressure measured the true airspeed at specific heights and distances from the blowers could be determined. Using this information everything from the size of the shapes, to the materials used to fabricate them could be determined. The most important information was the size of the flow stream, it was most important that the shapes did not leave the area in which the air flow was being generated. A list a various wind speeds at different distances was determined.

In order to find the flow velocities Equation 5 was used.

$$V = \left(2\frac{P_d}{\rho}\right)^{\frac{1}{2}} \quad (5)$$

Here V is the velocity of the flow, P_d is the pressure difference from the pitot-static tube, and ρ is the fluid density. To check these values another instrument was used to varify the values. The values are as follows.

Distance (m)	Veloctiy (m/s)
0	15.3
0.076	15.0
0.154	14.5
0.229	14.5
0.305	13.9
0.381	12.9
0.457	12
0.533	10.9
0.610	9.7
0.686	9.1
0.762	8.6
0.838	8
0.914	7

Table 5 - Wind Velocities

From these values an average velocity was found, 11.6 m/s. This will be used to find the various drag forces on the shapes.

Drag Analysis

To find the amount of force being produced from the wind on to the attachment, basic calculations were necessary. To ensure that the only difference between the two attachments were the shapes the velocity, frontal area, and density of air were kept constant. The only variance in the equation was the coefficient of drag, which is based on geometry. Seen in the equations below are the actual calculations.

$$F_{dc} = \frac{1}{2}\rho V^2 C_{dc} A \qquad (6)$$

$$F_{ds} = \frac{1}{2}\rho V^2 C_{ds} A \qquad (7)$$

Here the force of drag for the sphere, F_{dc}, is found with Equation 6 ρ is the density of air, V is the flow velocity, A is the cross sectional area, and C_{dc} is the coefficient of drag for the sphere. The force of drag for the square, F_{ds}, is found in Equation 7 where C_{ds} is the drag coefficient of the square. The drag produced isn't very significant but it is enough to show the difference of drag forces between the two shapes. The difference in the drag forces between all the shapes allows for each to travel a different distance to the fans.

Shape	Theoretical Distance Traveled (m)
Shell	0.260
Bullet	1.05
Airfoil	2.68
Cube	0.479

Table 6 – Theoretical Distance Traveled

When compared to actual distance traveled by each of these shapes, they are much smaller. This is the result of just looking at the drag force on the shapes. In reality there is also the friction between the cart and the track along with the drag that is produced by the cart and shaft that supports the shapes. When these other forces are present the shapes traveled a smaller distance.

Shape	Distance Traveled (m)
Shell	0.205
Bullet	0.875
Airfoil	1.00
Cube	0.375

Table 7 - Distance Traveled

The airfoil as predicted made it to the end of the track followed by the bullet, cube, and finally the shell. These are the results that we expected to see.

Another issue is if the drag force of the attachments would be able to produce enough torque to possibly tip over the carts, but the max torque calculated is only $0.038 ft - lb$ so the problem of torque will not be an issue. Upon testing, the shapes did not tip therefore the torque produce was in fact not an issue.

Spring compression length was determined through the above drag calculations as well as the total weight of carts when loaded. Based on testing with the blowers turned on it was necessary to tilt both tracks and allow for the weight of the carts to be allowed to work against the rolling friction forces that are present in both carts; both tracks are tilted the same amount and race results are consistent across either track. This also allows all shapes to reach the end of the track regardless of weight, as the only factor that should impact cart performance is the force of drag on each shape.

When stopping each cart with magnetic attraction to a steal plate it was necessary to increase the time of contact and speed 0 for the carts at higher impact velocities, as a light weak magnet is used to generate the attractive force it was possible for the impact force to overpower the magnetic one and the cart had a tendency to drift down the track the wrong way. By adding an elastic material behind the steel plate this time could be increased and the carts remain at one end of the track reliably.

7. Environment, Health, and Safety

Environmentally the Drag Racing project poses very little threats. The display only requires a 12V wall outlet to operate so the most harm to the environment would be caused by the possiblity of an electrical fire. In the creation of the display there were no steps taken that would have caused environmental harm.

The most important aspect of a design such as this is its safety. Any injuries or failures as a result of the design specifications are unacceptable. The individuals operating the display should have no worries about their health and safety. The display is intended for K-12 users so it has been outfitted to be as safe as possible, because kids tend to be accident prone. The biggest issues for safety would be when the user is exchanging the shapes on the carts, because the shapes are all aluminum they are relatively heavy so if the user were to drop one of the shapes it might cause some injury to someone. The other serious issue that could happen is if there were to be a short circuit in the system and someone were to accidently come in contact with it, although the chance of that happening is very low it is still a possibility when working with electronics. Overall there is little issues with the health and safety of the users, there is also almost no issues with the safety of the environment.

Also important as to the safety of the viewers is the results of the display themselves. It is important that the resetting and operation of the display methods be controlled and peaceful. Loud, knocking, or collisions may upset some viewers or lead to cyclical failures over longs periods of operation. It is vital that throughout all stages of display cycles that any stage shifts be controlled and gradual. Another important aspect of safety is the noise of the blowers. They must not exceed a volume that would provide discomfort for any viewer, this requirement drives the designs that limit intake blockage and blower securing methods.

8. Conclusion

With the completion of the project, the user will have the capability to chose two shapes. From this they will be able to determine which will have less drag. The goal was to have the airfoil reach the end of the track to generate a reponse. The other shapes will follow the airfoil in the following order, bullet, square, and shell. It was found that the shapes could not generate enough torque to tip. The attractiveness of the overall project was achieved by but the electcial system and the design and shapes themselves. The wind tunnel is very easily understood and user of in the range of K-12 will be able to use without any instruction needed.

9. Acknowledgements

On behalf of team 13 we would like to thank our advisors Dr. Chiang Shih and Dr. William Oates for allowing us use of their labs and helping finalize the design of the project. We would like to thank Professor Keith Larson and Jeremy Phillips for helping us machine all are necessary parts for the completion of the project. We would also like to thank Dr. Srinivas Kosaraju, Rob Hovsapian, and Dr. Matthieu Dalban-Canassy for overseeing our project and ensuring we met our goals on time. Finally we would like to thank Dr. Oscar Chuy for allowing us use of his lab, helping us with the electrical system, and allowing us to borrow necessary electrical parts to finish the system.

10.Future Plans

For future use of this project would to be add in more functions. This can range from a smoke display to more shapes to be used. Possibly expand the display to show more than just the velocity but the drag force being produced. The box itself could be expanded to accomidate for more activites.

11. Appendix A - Calculations

Following calculations done using MathCAD.

Coefficent Circle

$C_{dc} := 0.47$

Coefficient Square

$C_{ds} := 1.05$

Radius

$r := 1.1284\,in$

Length, width

$L_s := 2in$

$W_s := L_s$

Cross Sectional Area Circle

$A_c := \pi \cdot r^2 = 4 \cdot in^2$

Cross Sectional Area Square

$A_s := L_s \cdot W_s = 4 \cdot in^2$

velocity of air @ 0in

$V_0 := 51.837 \frac{ft}{s}$

Velocity of air @10in

$V_{10} := V_0$

Density of air

$\rho := 0.075 \frac{lb}{ft^3}$

Drag for circle

$F_{dc} := \frac{1}{2} \cdot \rho \cdot V_0^2 \cdot C_{dc} \cdot A_c = 0.041 \cdot lbf$

Drag for Square

$F_{ds} := \frac{1}{2} \cdot \rho \cdot V_0^2 \cdot C_{ds} \cdot A_s = 0.091 \cdot lbf$

$F_{dc} - F_{ds} = -0.05 \cdot lbf$

http://www.pasco.com/prodCatalog/ME/ME-6951_gocar/

height above cart

$h := .127m$

Torque generated by drag circle

$\tau_c := F_{dc} \cdot h = 0.017 \cdot lbf \cdot ft$

Torque generated by drag square

$\tau_s := F_{ds} \cdot h = 0.038 \, lbf \cdot ft$

Torque

$Press := 150Pa$ $\quad A := 3.912 in^2$ $\quad r := 0.431 in$

$\tau := Press \cdot A \cdot r$

$\boxed{\tau = 3.057 \times 10^{-3} \cdot ft \cdot lbf}$

Distance Traveled

$$C_d := \begin{pmatrix} 2.3 \\ .295 \\ .04 \\ 1.05 \end{pmatrix}$$

$a := 4.032\times 10^{-3}$

$\rho := 1.204$

$v := 11.646$

$k := 19.1\dfrac{lbf}{in}$ $\quad X := 1in$ $\quad W_s := -\dfrac{1}{2}\cdot k\cdot X^2$

$k = 3.345\times 10^{3}\cdot\dfrac{N}{m}$ $\quad X = 0.025m$ $\quad W_s = -1.079J$

$W_s\cdot 2 = -2.158J$

Given

$$\frac{2.158}{C_d\cdot\rho\cdot v\cdot a} = 31.586x^3 + 35.02x^2 + 51.77x$$

$$\text{find } x := \begin{pmatrix} 10.24 \\ 41.339 \\ 105.543 \\ 18.858 \end{pmatrix} in$$

$shell := 10.24in$

$bullet := 41.339in$

$airfoil := 105.543in$

$cube := 18.858in$

12. Appendix B - COMSOL

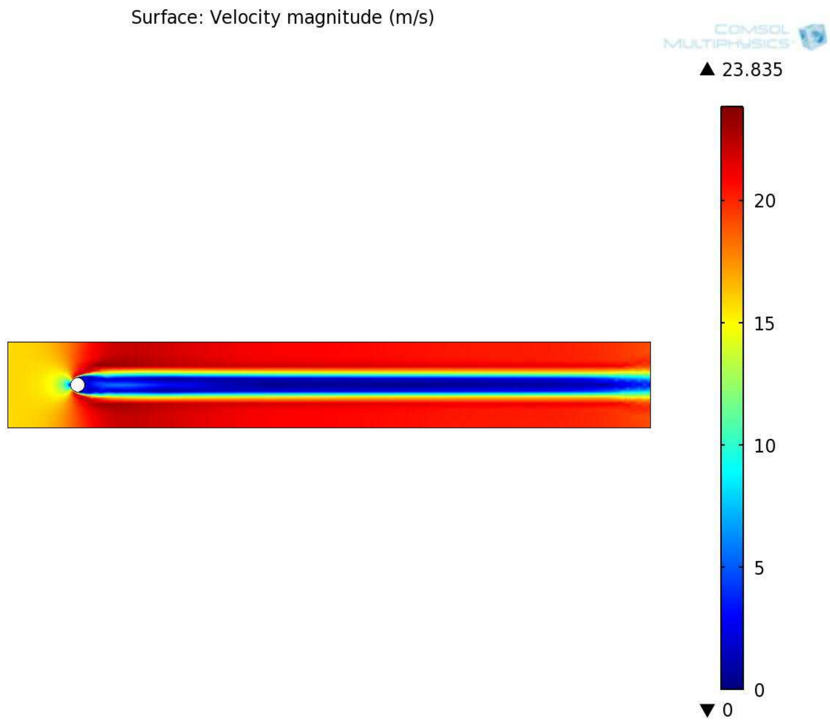


Figure 16 - COMSOL for sphere.

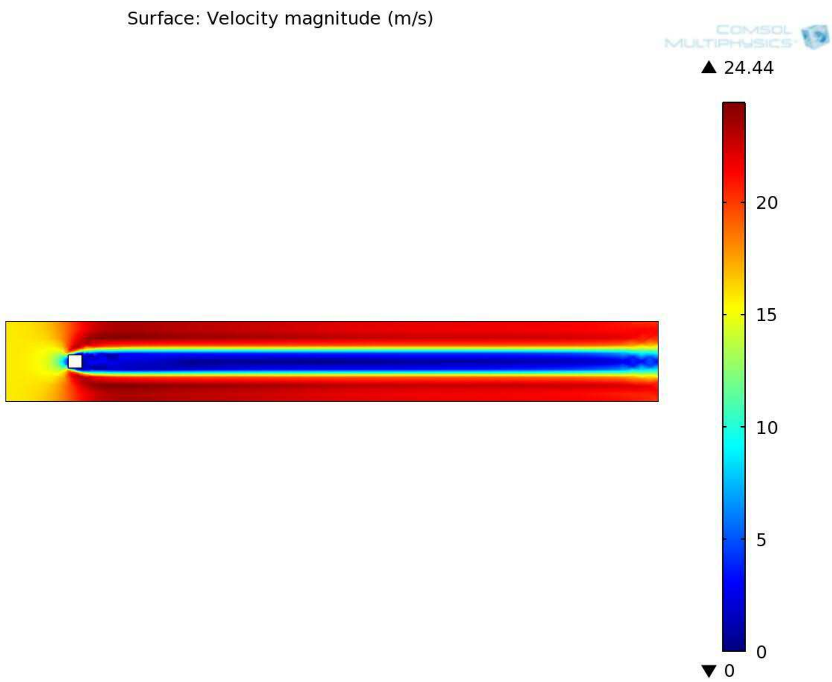


Figure 17 - COMSOL for cube.

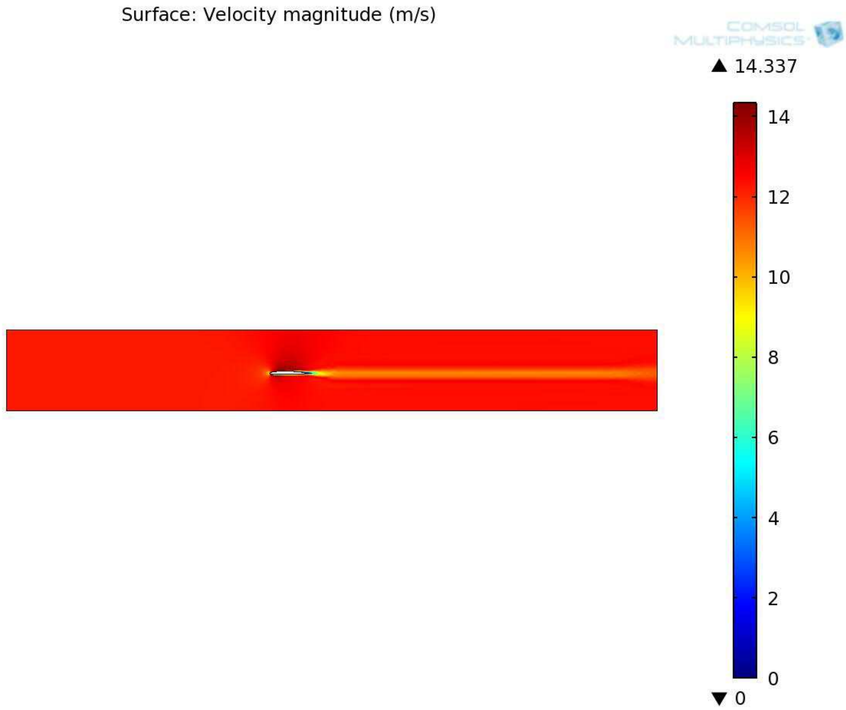
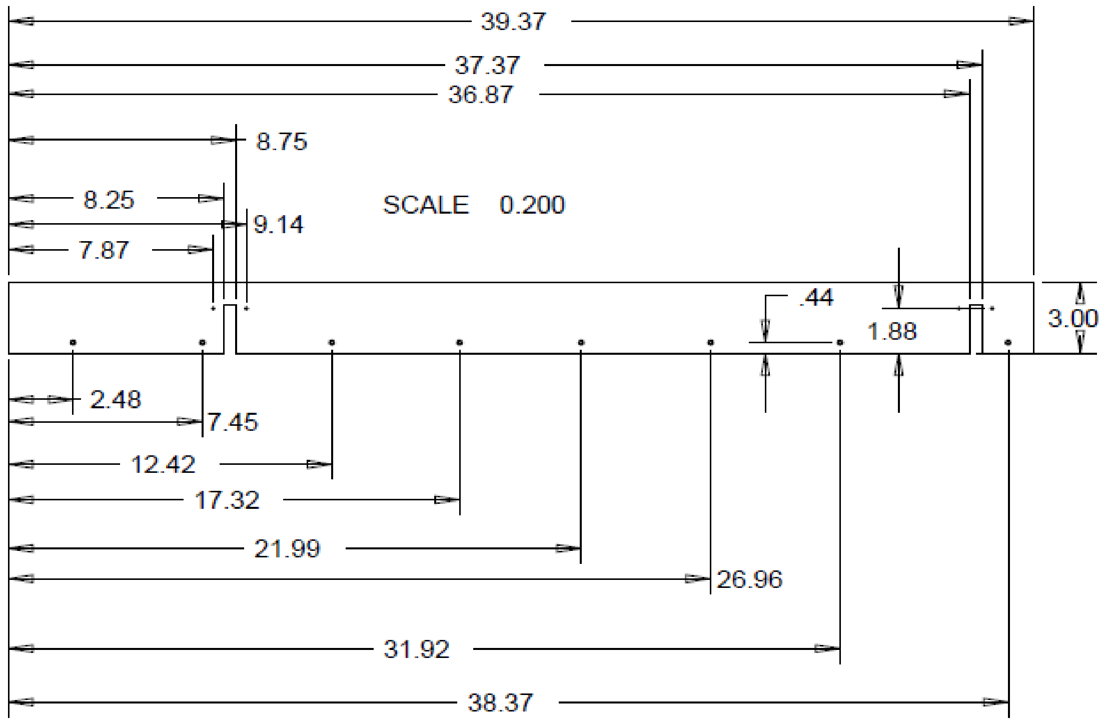
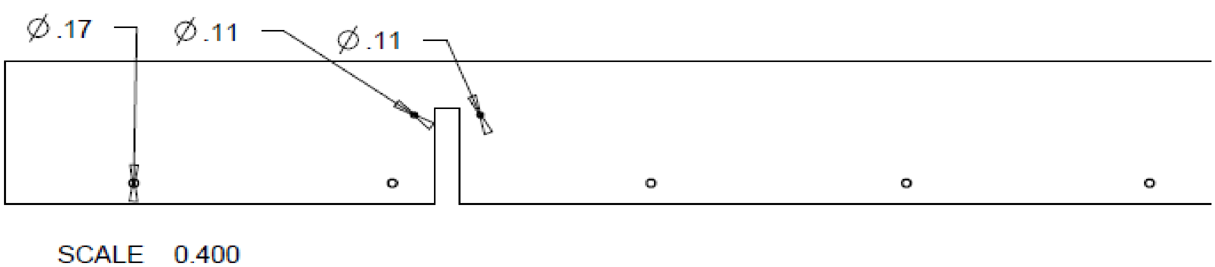


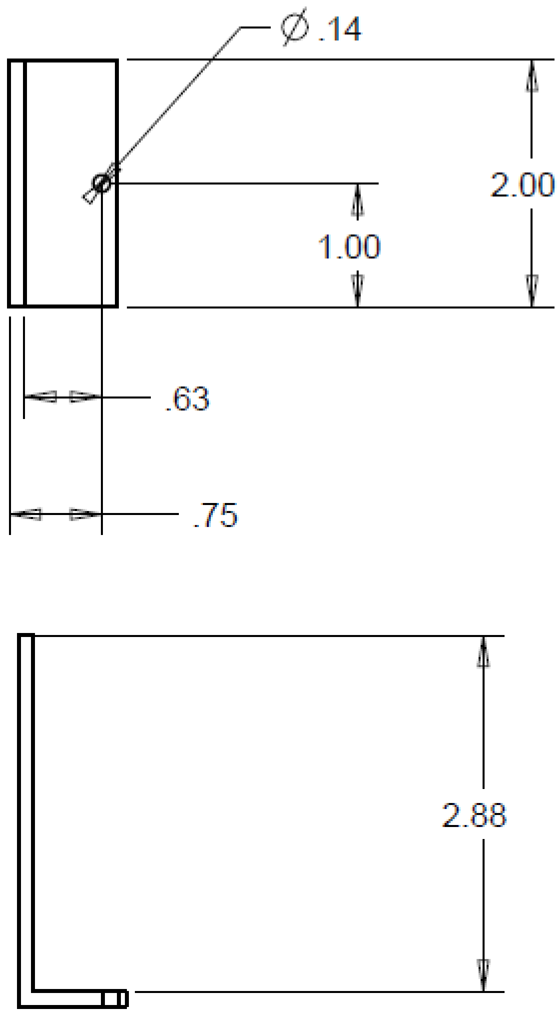
Figure 18 - COMSOL for airfoil at 0 deg.

13.Appendix C – ProE

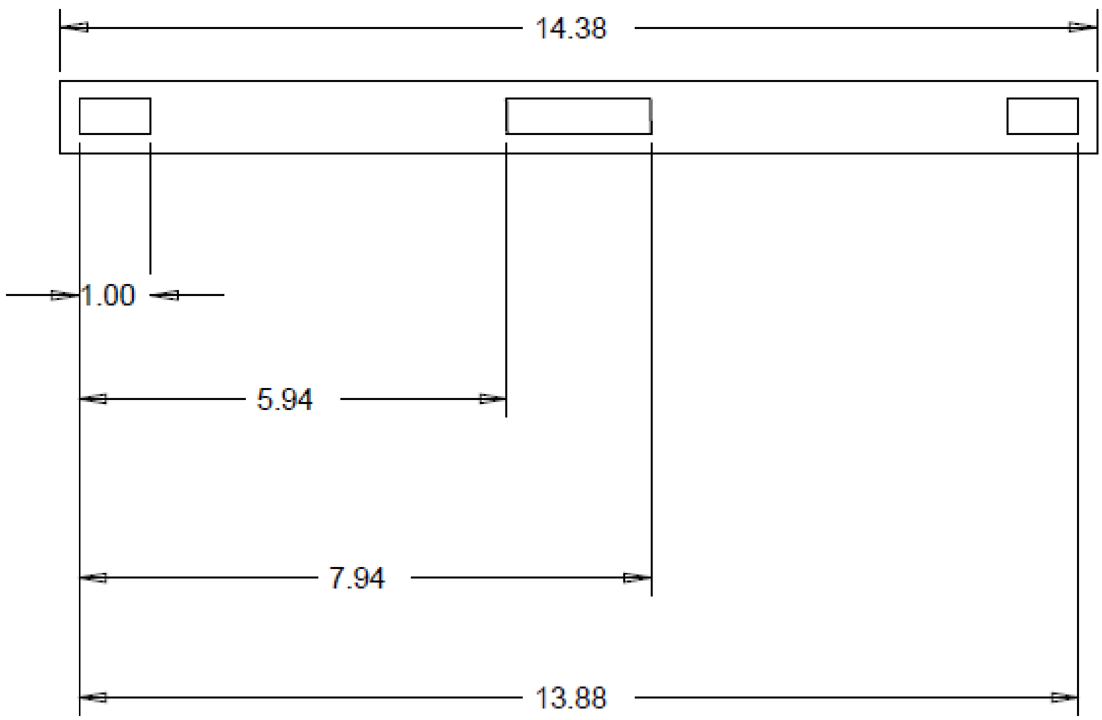




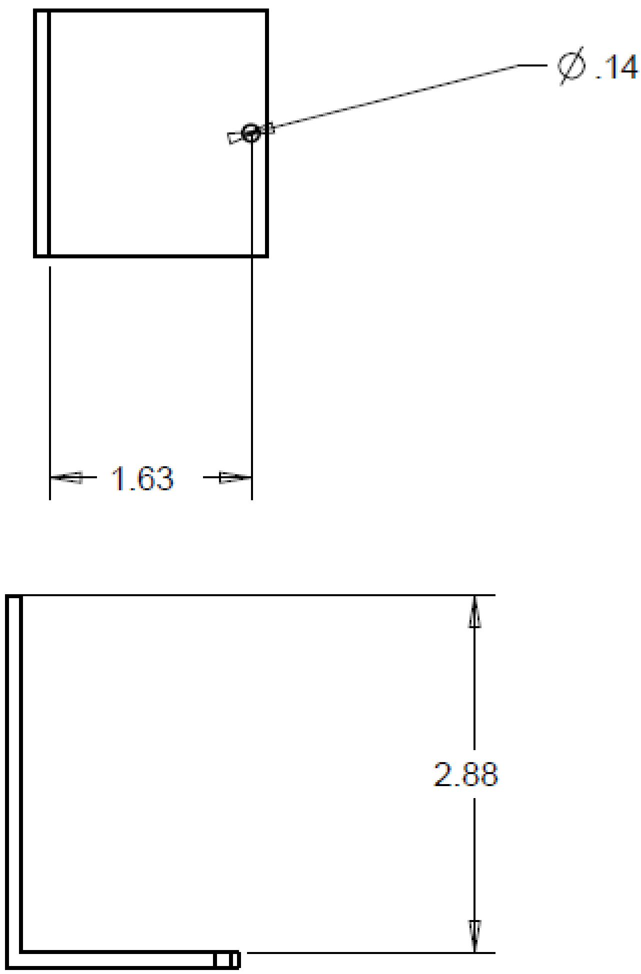
Part Name	Side Railing
Material	Plexiglass
Number of Parts	4
Units Measured	inches



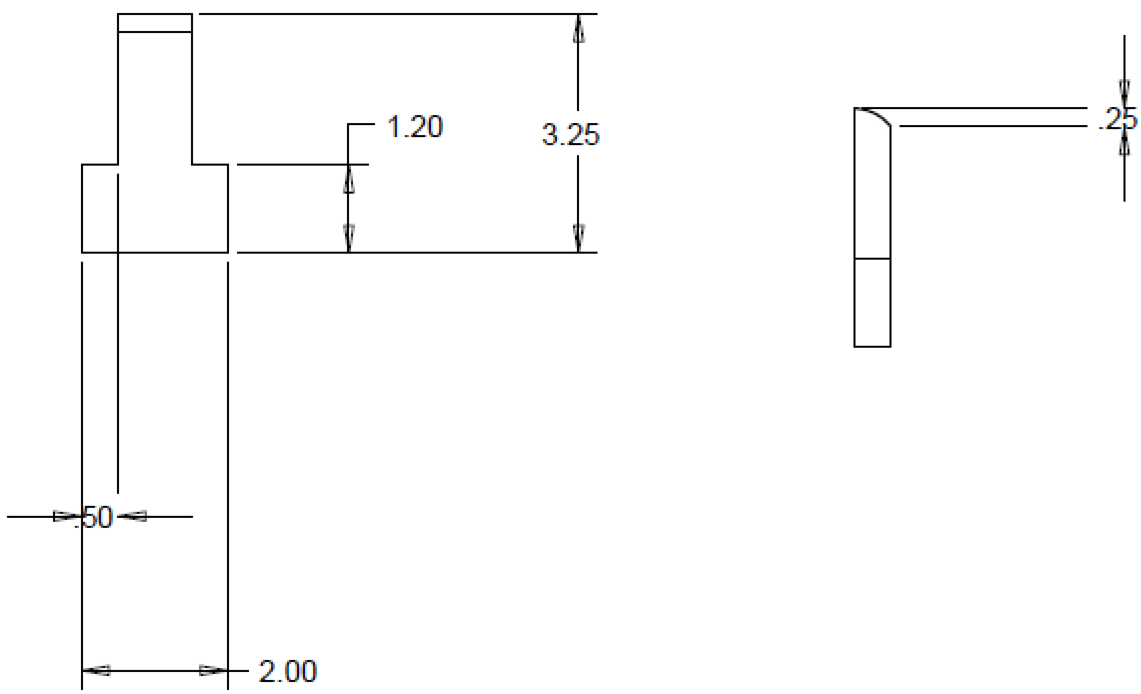
Part Name	Starter Support
Material	Steel
Number of Parts	2
Units Measured	inches



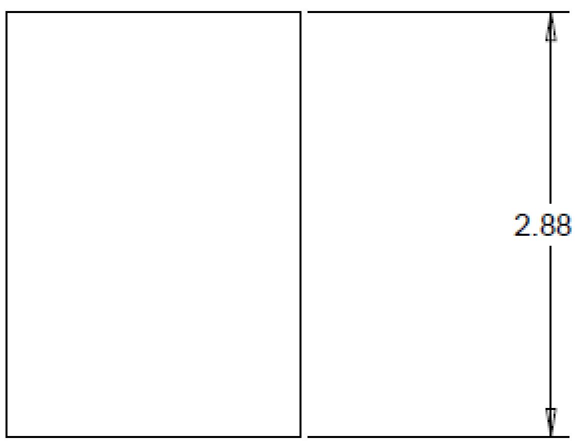
Part Name	Gate Bracket
Material	Aluminum
Number of Parts	1
Units Measured	inches



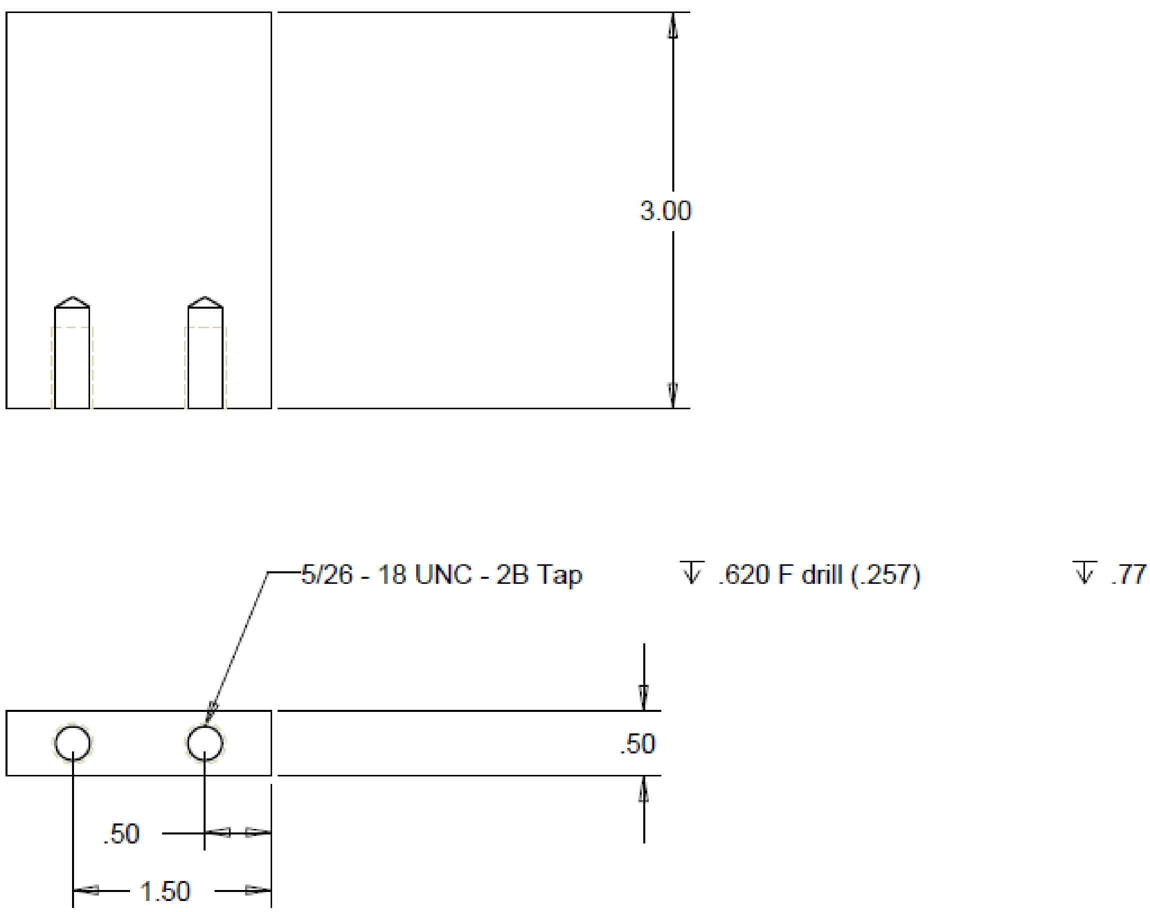
Part Name	Stopping Support
Material	Steel
Number of Parts	2
Units Measured	inches



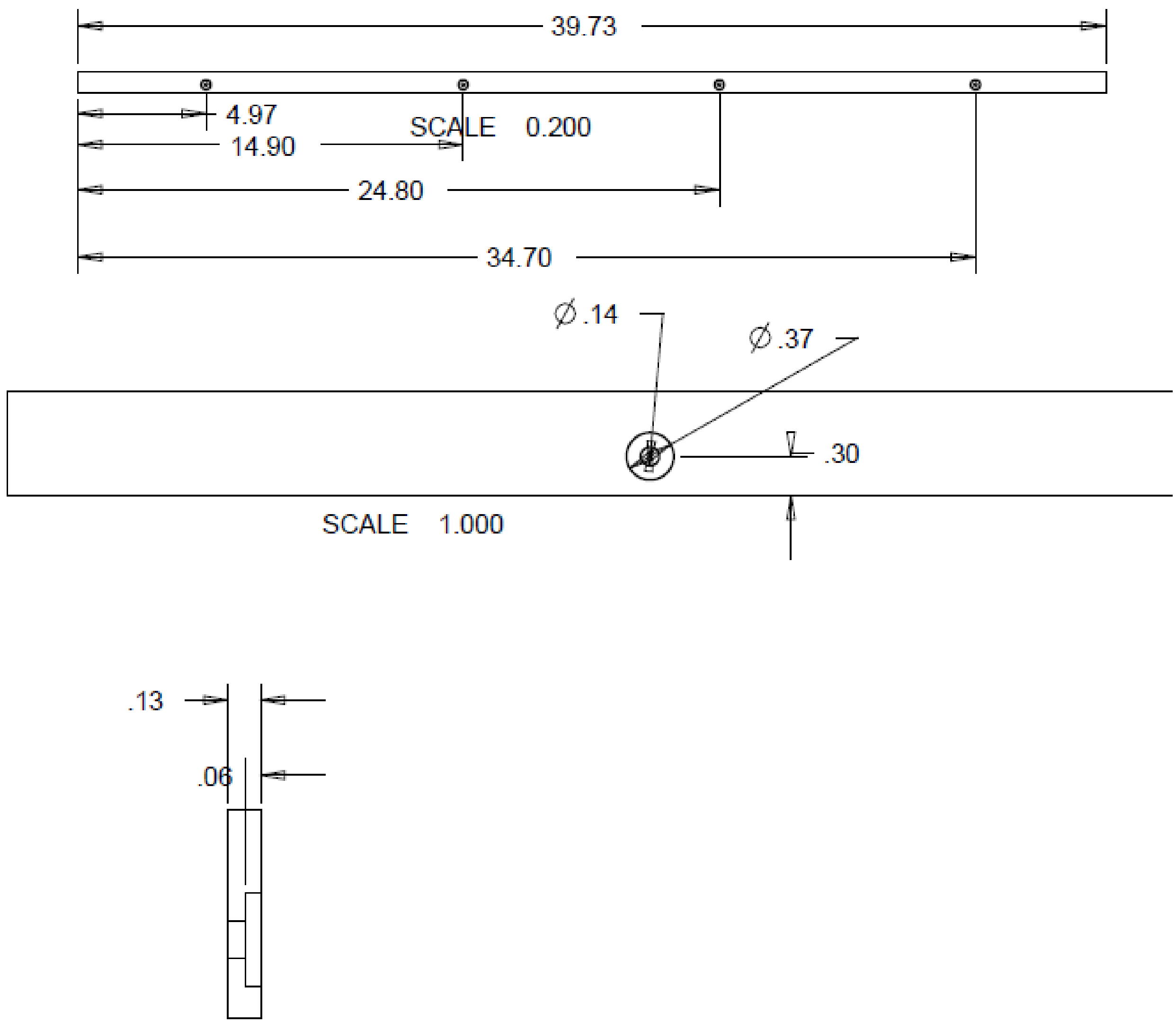
Part Name	Starting Gate
Material	Aluminum
Number of Parts	2
Units Measured	inches



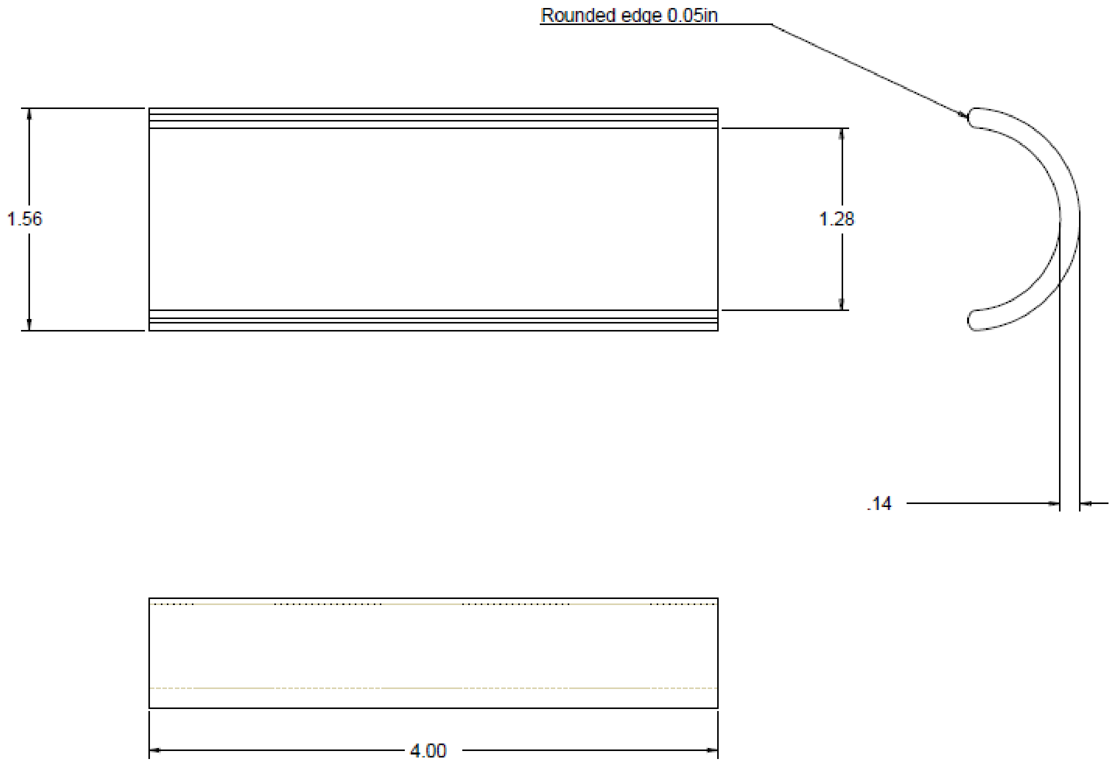
Part Name	Stopping Contact Surface
Material	Steel
Number of Parts	2
Units Measured	inches



Part Name	Bracket Support
Material	Aluminum
Number of Parts	1
Units Measured	inches

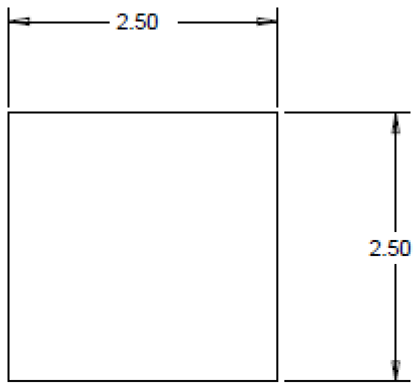


Part Name	Side Railing Top Sec.
Material	Plexiglass
Number of Parts	4
Units Measured	inches

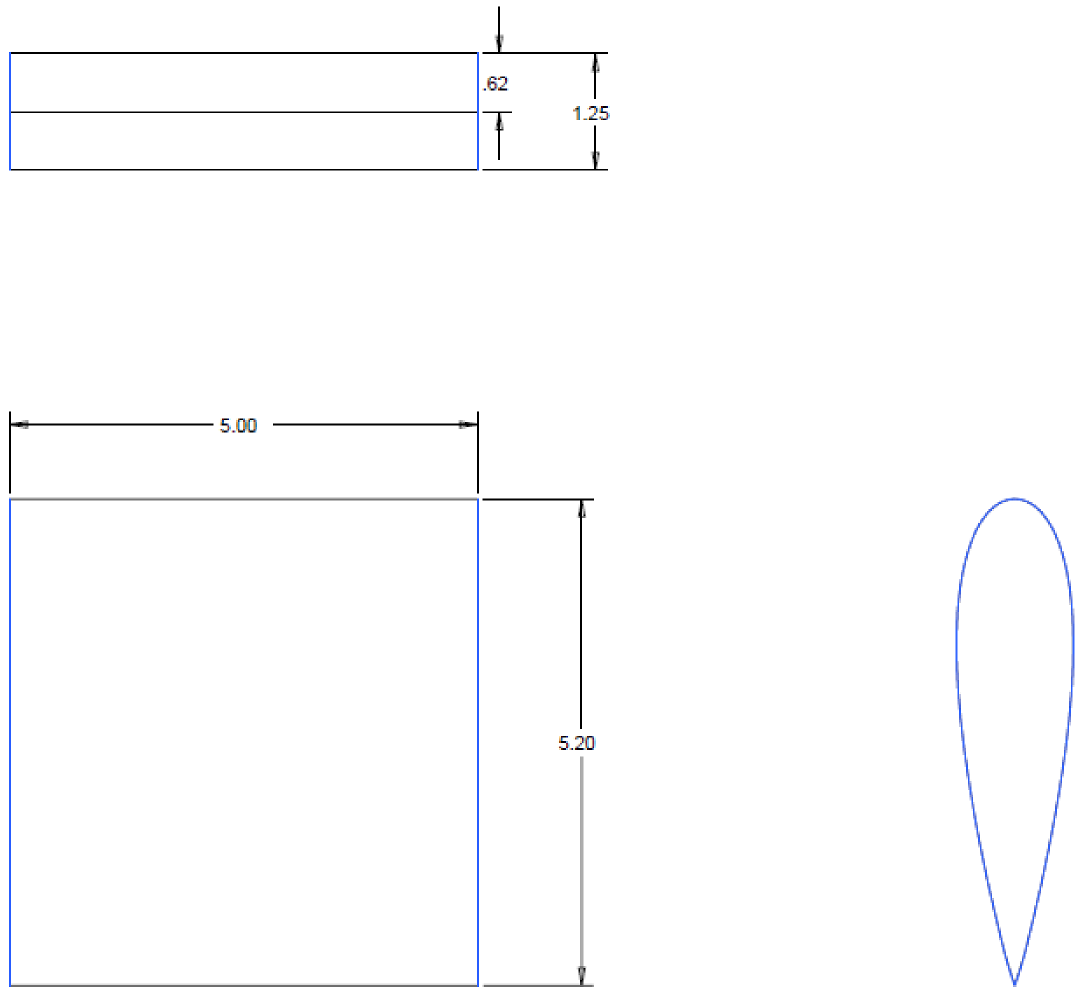


SCALE 2.500

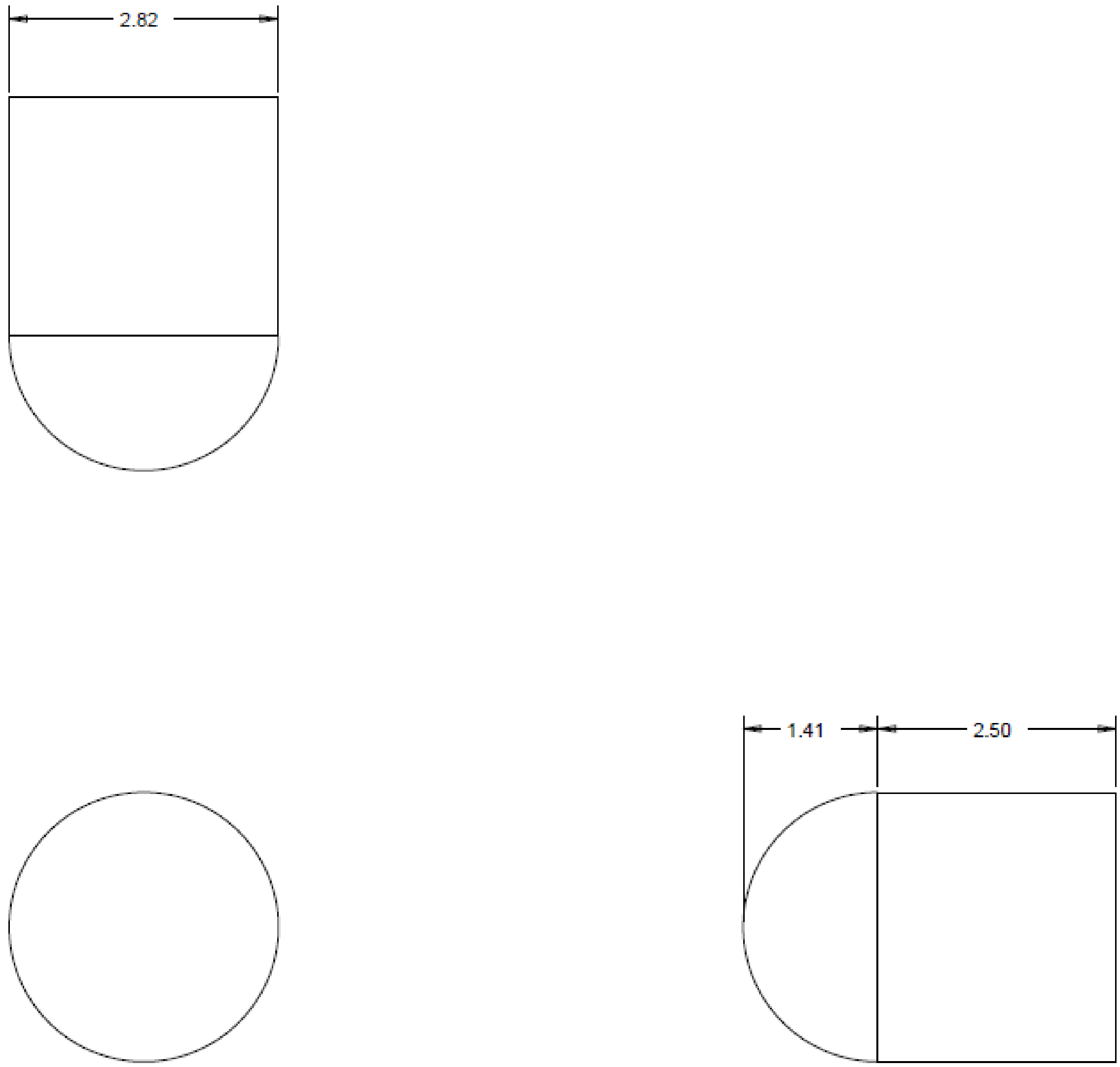
Name:	Jonathan Glynn
Project:	Drag racer/ Brogans museum
Part:	Shell, rod



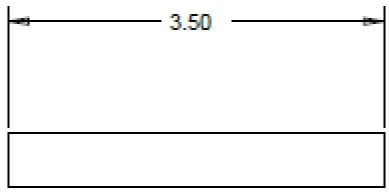
Part Name	Cube
Material	Aluminum
Number of Parts	1
Units Measured	inches

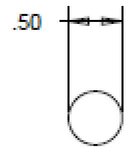


Part Name	Airfoil
Material	Aluminum
Number of Parts	1
Units Measured	inches

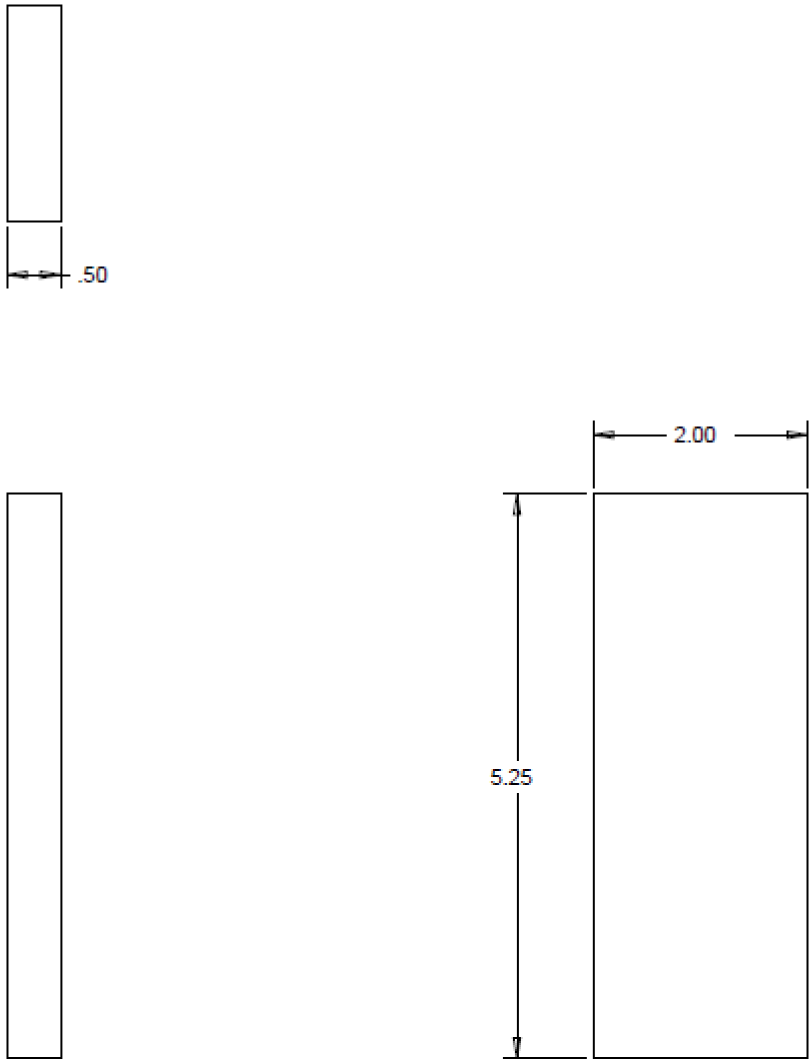


Part Name	Bullet
Material	Aluminum
Number of Parts	1
Units Measured	inches





Part Name	Rod
Material	Aluminum
Number of Parts	4
Units Measured	inches



Part Name	Baseplate
Material	Aluminum
Number of Parts	4
Units Measured	inches

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15.Biography

Jonathan Glynn, born in Toronto, Ontario, Canada and moved to the United States in middle school. Has a dual citizenship to the United States as well as Canada. Hometown is located in Tampa, Florida where he graduated in the top 10% of 2008 class of H.B Plant High School. Currently attending Florida State University and is going to receive a Bachelors in Science from the FAMU-FSU College of Engineering in Mechanical Engineering on April 28th 2012, also registered to take the Fundamentals of Engineering exam on April 14th 2012.

Joseph Cognato, born in Fort Lauderdale, Florida; only child with both parents still living. Graduated from Cardinal Gibbons High School in 2008 and plans on graduating FSU with a bachelors in Mechanical Engineering in 2012; after which will attempt to get a masters in mechanical engineering from FSU. While in his junior year as an undergraduate he decided that further education was more important to him than rushing into industry; He found current research at FSU in Aerodynamics to be interesting and is currently working toward getting involved in such research.

Leonardo Oliveira, Brazilian citizen and studying at FAMU-FSU College of Engineering for the spring semester. He was approved to study Mechanical Engineering on Federal University of Itajuba in 2009. University is located in Itajuba, Brazil. Besides mandatory courses that he has taken, he also has been participating in different activities inside the University. He was a member of the SAE Aerodesign Team and also part of research projects into avionics field. Now he is part of the exchange program, CAPES/FIPSE, which Florida State University and Federal University of Itajuba are partners.

Matthew Hartman, born in Tullahoma, Tennessee on April 5th, 1990. His father was in the United States Airforce and stationed in many states throughout his career. He graduated from Lake Braddock Secondary School in 2008 and decided to study mechanical engineering at Florida State University. Here he found a foundness to study deeper into the material science disipline of mechanical engineering. He is registered to receive his Bachelors in Science from Florida State University on April 28th, 2012. After he has graduated he will begin his career as a Management Associate with Gerdau Long Steel North America.

Figure 19 - From left to right, Joe, Leo, Matt, Jon