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EML 4905 Senior Design Project

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REQUIREMENT FOR THE DEGREE OF

BACHELOR OF SCIENCE

IN

MECHANICAL ENGINEERING

SAE BRAZIL AERODESIGN COMPETITION

Final Report

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

Ethics Statement and Signatures

The work submitted in this B.S. thesis is solely prepared by a team consisting of Andres Cardenas, Arjav Patel and Nestor Paz and it is original. Excerpts from others' work have been clearly identified, their work acknowledged within the text and listed in the list of references. All of the engineering drawings, computer programs, formulations, design work, prototype development and testing reported in this document are also original and prepared by the same team of students.

Nestor Paz	Andres Cardenas	Arjav Patel
Team Leader	Team Member	Team Member

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Abstract

The SAE Aero Design Brazil is an international engineering competition sponsored by SAE International that held its 16th annual competition in Sao Jose Dos Campos, Brazil from 30 October to 2 November. The purpose of the competition was to design, manufacture and fly a radio controlled (RC) airplane to carry as much payload as possible within the restrictions set by SAE. The competition attracts engineering teams from all over the world, and encourages them to design original and efficient aircraft.

The team anticipated participating in the competition and representing FIU under the name PanthAir Cargo. As such, the design, manufacturing and eventually successfully flying our prototype was accomplished on time and according to the competition rules. Unfortunately, neither our team, nor any other team from the United States was able to secure a slot to participate in the competition in Brazil. Therefore, we can only make a relative comparison of the performance of our aircraft to the official results published after the event.

Special emphasis was placed on engineering theoretical and experimental calculations. The team designed an aircraft as light as possible in order to lift as much payload as possible while respecting all design restrictions. SolidWorks Computer Aided Design (CAD) software was used to aid the design and stress testing of the aircraft. Tradeoff studies were conducted on many parameters of the aircraft like the configuration of the wings. The software XFLR5 was used to analyze our chosen airfoil in order to obtain maximum drag and minimum lift at various Reynolds numbers and angle of attack.

The team designed the best possible aircraft given very limited resources and manufacturing capabilities. The team found an excellent RC airplane pilot within the current FIU student body. He attended our team meetings, offered his expertise from his own experience perspectives, and participated in the manufacturing process. It was the team's intention to take our pilot with us to the competition in Brazil.

FIGURE 1: Team Picture

Shown in Figure 1 above from left to right are Arjav Patel, Andres Cardenas, Kishan Kalpoe and Nestor Paz.

1. Introduction

1.1 Problem Statement:

“To design and build a remote control airplane capable of competing on an international level within a given set of rules and parameters” is our problem statement. The event is sponsored by the Society of Automotive Engineers (SAE). The organization changed its name in 2006 to SAE International to reflect the increasingly international character of its activities. According to their website, they have more than 138,000 engineers and related technical experts in the aerospace, automotive and commercial-vehicle industries [1]. Their core competencies are life-long learning and voluntary consensus standards development. SAE International's charitable arm is the SAE Foundation, which supports many programs including the Collegiate Design Series. The SAE Aero Design Series falls under that effort.

SAE International hosts three Aero Design series competitions a year. Two are held in the United States in the spring, and one is held in Brazil in the fall. Due to FIU’s senior design timeline, the competition that would be appropriate for the team to enter would be the one in Brazil. It is also referred to as the *SAE Brasil Aero Design Competition 2014*. Additionally, the rules differ from year to year and between events. Therefore, a plane designed to compete within the rules for the *SAE Brasil Aero Design Competition* would not qualify for an *SAE East* or *West Aero Design Competition*. Some of the differences include allowed aircraft sizes as well as propulsion requirements. For example, the competition in Brazil requires internal combustion engines while the ones in the United States require electric motors.

The competition is divided into three classes: Micro, Regular and Advanced. The class that we would be competing in is the Regular class. This class offers the best chance to compete within our very limited resources. The Regular class also offered the best opportunities to learn and apply sound mechanical and aerospace engineering principles because it does not allow for computer assisted flight controls to be used. Although these types of electronics often help improve the performance of any aircraft, sometimes they can also be used to compensate for design flaws.

The rules allow for the collegiate teams to be comprised of up to 15 members. Obviously, any team having that many people working towards the same goal greatly enhances their chances to succeed.

This competition is governed by a set of rules and regulations that have been included in Appendix 1. According to their rules, in order to succeed a team must perform the following (translated from Portuguese):

- Careful analysis of the competition rules
- Consistent conceptual and preliminary design
- Definition and / or preparation of the design methodology
- Preparation and / or set of analysis tools (calculations)
- Design details
- Construction, construction quality, robustness and reliability of the project
- Preparation and essay development engineering
- Preparation of the report
- Planning and preparation of the oral presentation
- Competition flight

According to the rules, the following should also be considered in order to succeed:

- Seeking sponsorship (financial support)
- Planning
- Effective Leadership
- Teamwork
- Logistics
- Communication skills
- Interpretation of rules and additional documents
- Creativity and Innovation
- Having good sportsmanship

1.2 Motivation

The team seeks to work on a project that would provide the opportunity to come up with innovative ideas and applying them to the field of aerospace engineering. Choosing a design capable of competing in the SAE Brazil Aero Design Competition also provides the following motivations:

- To build an airplane capable of competing in a world class event
- Potential for increased funding for future projects
- Leaving a legacy behind for future students to follow

1.3 Literature Survey

The very first piece of literature that had to be carefully study was the SAE Brazil Aero Design Competition Rules. These rules provide a set of parameters and boundaries from which we would not be allowed to violate. These rules are written in Portuguese, which to some degree presented a challenge in trying to determine the correct translation. Since the rules differ from year to year and between events, the rules written in English for the competitions in the United States were not helpful.

Other literature that has been researched is the reports and results from previous universities that have previously competed in *SAE Aero Design Competitions*. There are plenty of proven ideas that can be found in this kind of research as well as ideas that were found to have been not so good. In fact, in some cases bad design ideas led to catastrophic failure and loss of the airplane. As such, a priority has been placed on trying to learn from previous mistakes as much as possible.

Research on aircraft manufacturing techniques has also been done and is also of great importance to us. Considering the small size of the team and that it comes with very limited resources, a major consideration for this design will be the feasibility of manufacturing during the selection of concepts and designs. For example, the team has extensively researched manufacturing the wings using Styrofoam because of the potential savings of time and money.

The engine and propeller combinations were also researched. It has been found that some of the allowed engines have previously been tested with different propellers in order to determine the best thrust producing combinations. That kind of research alone would have required many of hours of testing.

The engine and propeller combination was extensively researched because this is the power of the airplane. Any increase in available thrust directly impacts the take off distance. . The SAE Aero Design rules for Brazil 2014 gave a set of engines teams had to choose from, including the Magnum XLS-61 and OS 61FX. Below is a summary of engine specifications that were researched and to help the team make a well educated decision for choosing the engine:

TABLE 1: Engine Specification Comparison [2], [3], [4], [5], [6] and [7]

Engine name	Cost	Size	Bore	Stroke	H.P.	Weight (Wo/Muf)	Muf	Static Thrust
R&B 6170	$109.99/ $157.50	0.61 cu in	0.94/23.8 8mm	0.88/22.3 5mm	1.8 @15,000 RPM	14.25 oz	3.7 oz	
OS 61FX	$144.99	0.61 cu in	0.945 in	0.866 in	1.9	19.40 oz		7.7
Magnum XLS 61	$99.99	0.607/.61 cu in	.96 in/24.0 mm	.81in/22. 0mm		22.5oz		8.91
O.S. 55AX	$149.99	0.545 cu in	.91in/23 mm	.85in/21. 5mm	1.75 HP @16,000 RPM	14.29 oz		

The R&B 6170 did not have much availability in the market. Most teams choose to ignore this engine all together which is why there isn't more information available to research. The OS 61 FX a very steady and a very good choice, the only problem with this engine is that OS stopped manufacturing this engine in 2011 [8]. All the OS 61 engines that were available in the market were used, and the team did not want to assume the risks involved with a used engine. The OS 55 AX was the new engine that OS Engines started manufacturing after the discontinuation of OS 61 FX. This engine was better in terms of weight and size, however, the performance of this engine was a bit compromised because of the smaller size of the engine. The Magnum XLS-61 was the closest to the OS-61 FX in size and weight. The XLS seemed to have a little bit better performance than any of the other of the engines available to choose. The XLS-61 was also very popular with other teams and easily available in the market. It was also less expensive than the others.

The engine and propeller combination is directly correlated to the performance of the airplane. Any sort of improvement in performance especially power is always welcome. There are 2 important parameters that need to be considered while choosing a propeller. One is the pitch and the other is the diameter. For example a 12x3 prop means 12 inch radius and a 3 inch pitch. Engines usually have manufacturer's recommended propeller sizes including a recommended break-in propeller. For example, for a Magnum XLS61, the break-in size propeller is an 11x7. It is important to break in a brand new engine correctly to make sure to get proper performance and longevity from the engine.

Estimating the thrust is very important to predict how much weight will be successfully lifted. Since different propellers will give different amounts of thrust, it was important to know which engine and propeller combination would perform the best for our conditions. Below are some of the propeller static and dynamic thrust results other universities have performed using a Magnum XLS-61 engine:

TABLE 2: Propeller and Static Trust Results [9]

Propeller	RPM	Thrust (lb)
11X7	11,400	5.51
12X7	10,000	5.22
13X4	10,500	7.28
14X4	9,300	8.16

TABLE 3: Static Thrusts for Various Propellers [10]

Prop 1 2 Blade APC C-2 11x7			
f (Hz)	RPM	Strain (μ)	Thrust (lbf)
242	7260	0.00085	1.9
260	7800	0.0012	2.6
320	9600	0.0016	3.4
316	9480	0.00181	3.82
340	10200	0.002131	4.462

Prop 3 2 Blade K-Series 13x6			
f (Hz)	RPM	Strain (μ)	Thrust (lbf. oz)
220	6600	0.00094	2.08
250	7500	0.00128	2.76
270	8100	0.00135	2.9
300	9000	0.00142	3.04
370	11100	0.00234	4.88

Prop 2 2 Blade APC C-2 12x6			
f (Hz)	RPM	Strain (μ)	Thrust (lbf. oz)
250	7500	0.0012	2.6
270	8100	0.00145	3.1
300	9000	0.0018	3.8
320	9600	0.0021	4.4
340	10200	0.0023	4.8

Prop 4 3 Blade Master Airscrew 13x6			
f (Hz)	RPM	Strain (μ)	Thrust (lbf. oz)
230	4600	0.00034	0.88
320	6400	0.0007	1.6
360	7200	0.000859	1.918
400	8000	0.0015	3.2
530	10600	0.002125	4.45

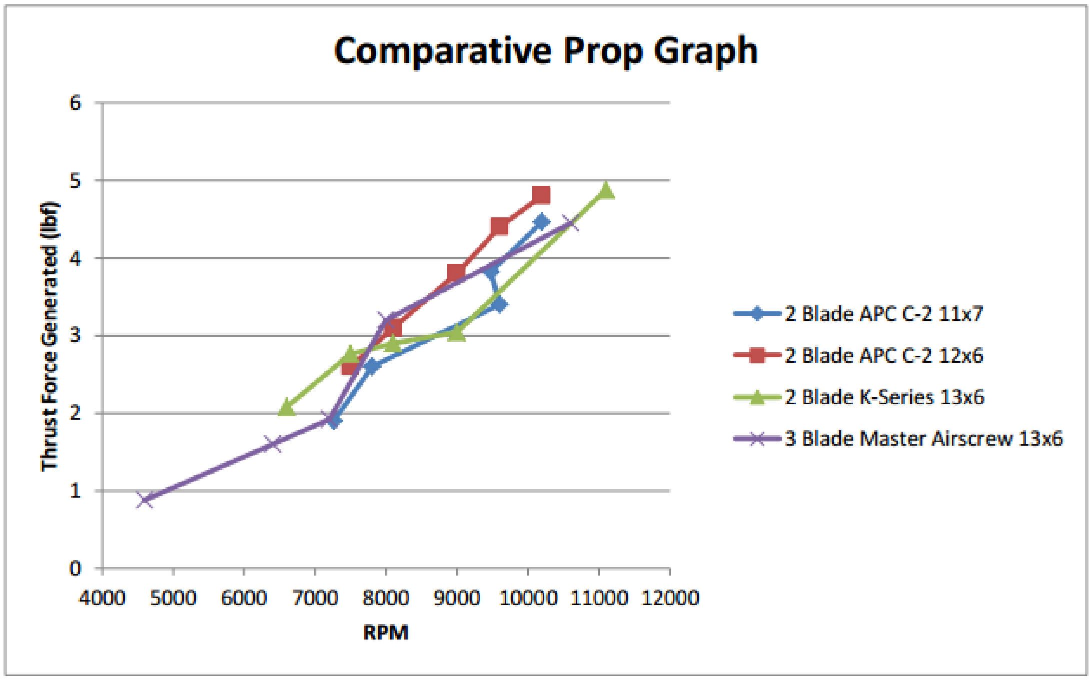

FIGURE 2: Static Thrusts for Various Propellers [10]

Just static thrust calculations aren’t enough to estimate performance throughout the full flight path. Dynamic thrust also plays a huge part in calculating performance of the plane. Students at Michigan tech used their wind tunnel to measure dynamic thrusts using wind velocities from 5 to 30 mph using various propellers on the Magnum XLS 61 engine. Dynamic results are shown in Figure 3.

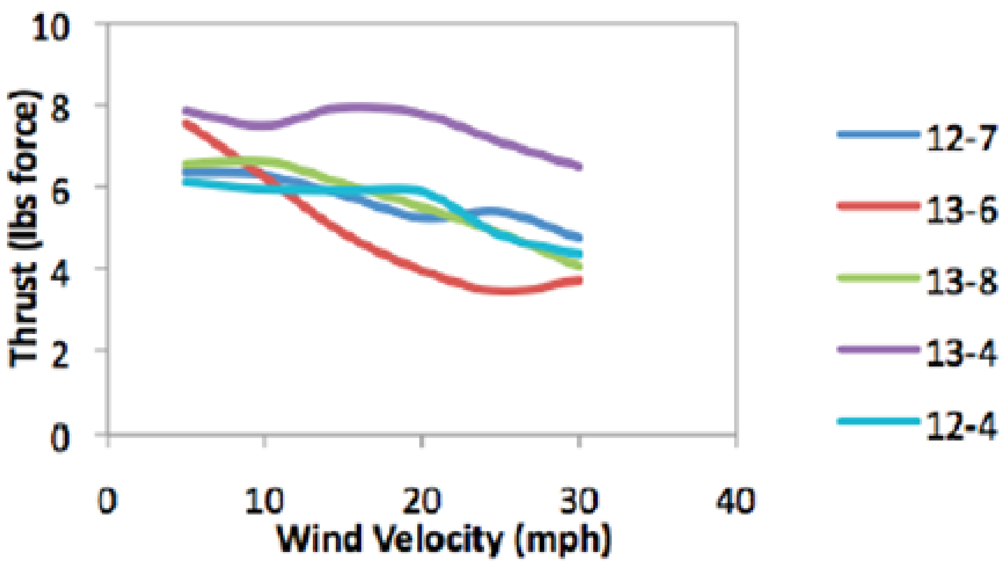

FIGURE 3: Dynamic Thrust for Various Propellers [8]

There was also a lot of literature researched to design and select the appropriate electrical and electronic components of the airplane including the transmitter, receiver, electric servos, on-board battery, battery sensors and wiring. A well performing combination of all of these components is necessary while balancing the weight, size and cost limitations.

Literature was researched for almost every component of the aircraft including, landing gears, wheels, tires, fuel tank, hinges, hardware and materials. The amount of literature available for researching all the components is almost limitless.

Design literature was also researched to assist in considering all the different design alternatives. An example of this research is the book *Aircraft Design: A conceptual Approach*, Fourth Edition, by Daniel P. Raymer. This is an extremely useful and helpful book when trying to select a design.

2. Project Formulation

2.1 Overview

This project was chosen because of the fact that it afforded the team to become exposed to many aircraft design challenges. Additionally, it was deemed that participating on an international level would be very exciting. The SAE Brazil Aero Design Competition is a world class competition with teams from all over the world attending.

2.2 Project Objectives

The main objective of this project is to design and build a radio-controlled airplane capable of competing in the *SAE Brazil Aero Design Series Competition*. The goal of the competition is to carry as much load as possibly while respecting the competition design parameters and restrictions. The *SAE Brazil Aero Design Series Competition* offers three different categories each one with its own challenges and rules: Micro, Regular and Advanced. The micro class was considered by the team to be too small of a project to be considered as a senior project thesis. The advanced class falls out of the capabilities of the team in terms of money, experience, and eligibility. Therefore, *PanthAir Cargo* decided to design and build an airplane capable of competing in the Regular class. This class will still provide significant engineering challenges as well as a total team effort to succeed.

As shown in the following figure, the aircraft is supposed to take off, fly around an oval imaginary circuit and land. It cannot perform any flight maneuvers or deviate from such circuit. The aircraft has a maximum take off distance of 200 feet and a landing distance of 400 feet. The maximum time allowed for take-off is 3 minutes, starting from the moment the judge gives clear signal for take-off.

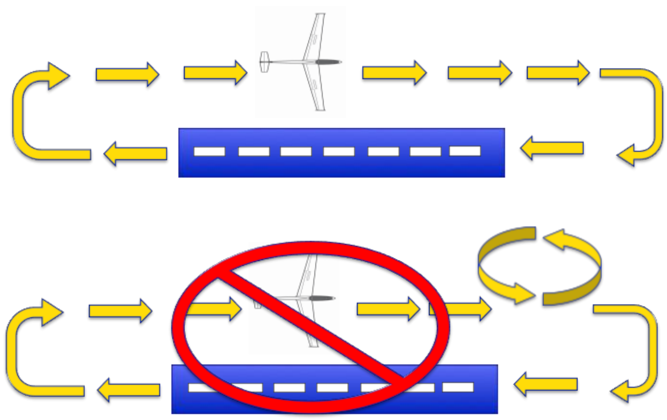

FIGURE 4: Allowed flight pattern for Regular Class [SAE Brazil Rules]

Teams will try to carry as much payload as possible. Points are awarded not only on the load carried but also on the final report, oral presentation and bonus points awarded if certain tasks are completed.

2.3 Design Specifications

The teams are encouraged to come up with innovative designs within a give set of competition parameters. For example, it is possible to design an airplane with a front canard wing, and having the engine at the rear.

In order to compete in the Regular Class of the *SAE Brazil Aero Design Competition*, there are design specifications called for in the rules that would have to be met. For example, the engine selected for propulsion must be from the approved list of engines in the rules. More specific information on the engine is included in the Engine Constraints section of this report.

There are many other design specifications outlined in the rules. For example, all the structural support connections have to be designed in such a way that they can be easily inspected for security and integrity before and during the competition. Another specification requirement is that all bolts must be secured with self locking nuts.

2.4 Constraints and Other Considerations

2.4.1 Geometric Constraints:

This year, the geometric design restrictions are based on a fixed area of the plan for view of the aircraft. Teams cannot exceed 1200 in^2 of planform area (top view of the aircraft). Minimum geometric requirements for the load compartment as well as restrictions on the engine are given by SAE.

The geometric restriction of the aircraft is based on a maximum plan form view area as depicted in the figure below:

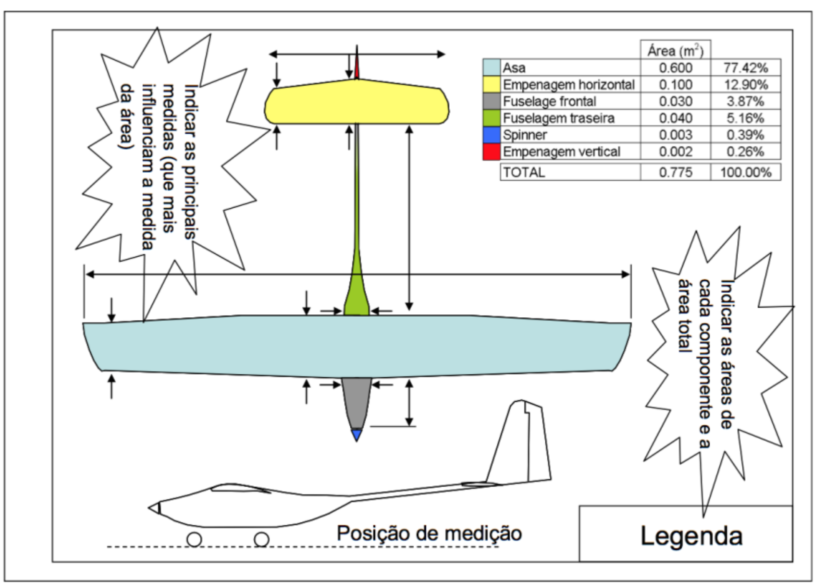

FIGURE 5: Geometric Restrictions [SAE Brazil Rules]

All lift-producing surfaces will be accounted for when calculating the total area even if they are on top of each other. In other words for bi-planes, the areas of both wings will be included in the calculation. The team will try to gain as much wing area as possible by reducing the fuselage area.

The Airplane must not exceed a maximum gross weight of 44 pounds, including the payload. For this reason, it is critical to reduce the weight of the unloaded aircraft in order to gain as much as possible in payload weight.

2.4.2 Engine, Propeller and Fuel Constraints:

The SAE Aero Design competition rules were very clear on the type of engine that can be used in the aircraft. The rules specify that teams can only make use of four different types of engines, and there would be no tampering with the engine and no sort of turbo boost to enhance the performance allowed. The team has to choose from these four engines: K&B 6170, OS 61 FX (no longer manufactured), Magnum XLS 61 and OS 55AX.

The fuel required for the competition is Methanol 10% nitro methane and 18% oil. Our team will be using the same fuel for our project.

The rules forbid the use of metal propellers. However, the size and pitch of the selected propellers was entirely up to the team. Propellers are a very important part of any airplane. Propellers come in various diameter sizes, pitch and materials. Selecting a propeller that is too big or having too much pitch will prevent the engine from operating at optimal RPMs thus not being able to produce the maximum amount of thrust. Too small or very small amount of pitch will allow the engine to achieve high RPMs, but may not produce the maximum thrust either. The propeller material is also important in producing thrust. A soft plastic propeller will bend more than a wood propeller allowing for more RPMs, but not necessarily more thrust. Finally, the static thrust generated will differ from the dynamic thrust. Obviously, a lot of trade-off analysis is required to make the best possible selection of a propeller and engine combination.

2.4.3 Cargo Bay Compartment:

The rules require that the cargo bay compartment contain a minimum of 293 in^3. The compartment has to contain six orthogonal sides, and must not be supported by the payload. It is left up to the teams to be as innovate as they wish as far as where they place the compartment or what dimensions to use in order to obtain the minimum planform area while at the same time allowing for the predicted amount of payload to be carried. The compartment does have to have one access door in order to replace the payload after the flight, and it must be totally enclosed.

The design and integration of the cargo bay proved to be one of the biggest challenges for our design. The design had to consider many factors including the effect on the planform area, the stresses on the airplane, the required access and locating it near the center of gravity of the aircraft.

2.5 Discussion

There have been some significant challenges that presented themselves in the course of determining the parameters and constraints that we needed to follow. The team was initially following the rules for the SAE East Aero Design Competition at the beginning of the semester. As a result, the original concept that was being considered was quite different. For example, the team initially considered an electrical motor in the first designs. The geometric requirements were also much different that made a more innovated design to be applied. However, in mid-February SAE Brazil published their rules, which need to be followed. The team was hoping they would be similar, but actually turned out to be quite different.

This last minute changing of the rules obviously affected the team's strategy and meant a delay of a couple of weeks as far as research and designs.

3. Design Alternatives

3.1 Overview of Conceptual Designs Developed

PanthAir Cargo considered a number of conceptual designs that were deemed to be successful in this competition. Very innovative concepts as well as more conventional concepts were considered. Some of the concepts and characteristics that were considered involved different variations of wings, empennage and fuselage combinations.

3.1.1 Major Components

The major components of our design include the cargo bay, wings, fuselage, empennage, engine/propeller, flight control surfaces, electronics and landing gear arrangement.

Some components such as the engine, propeller and electronics were selected from commercially available and authorized products. However, making wise selections based on sound engineering principles as well as looking for ways to save weight and keep costs down also played a big role.

The fuselage, wings, horizontal tail, vertical tail, engine mount and internal supports were all designed and built from scratch.

3.2 Overview of Wing Designs

Probably the most important design characteristic that will affect the performance of the aircraft is the wing design. It requires considering many characteristics such as airfoil design, wing location, dihedral angle and to a very large degree, the manufacturing feasibility of the design.

A desirable characteristic for wing design would be selecting a design that contributes to lateral stability. Such a characteristic is found on aircraft that have their wings mounted up high. Low and mid wing designs do not add to lateral stability.

The dihedral angle is the angle of the wings to the horizontal plane. The addition of a dihedral angle would add to stability, but it also creates a stress concentration point at the center of the two wings which has to be overcome by adding more stiffening and thus more weight.

Our aircraft wing will not be experiencing supersonic air flows. Thus it is not necessary to consider sweeping them in order to mitigate shock wave effects.

Lastly, it is deemed essential that the wings be capable of being easily manufactured. Given our lack of resources, this is deemed a high priority.

3.2.1 Wing Design Alternatives

The location, angle of incidence and dihedral angle are also important characteristics that affect the performance as well as the stability of the aircraft. Some of the wing concepts considered included high wing, mid wing and low wing as shown in figures 6, 7 and 8.

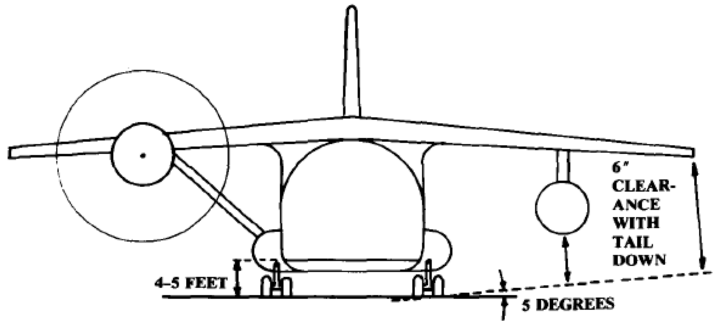

FIGURE 6: High Wing Design [11]

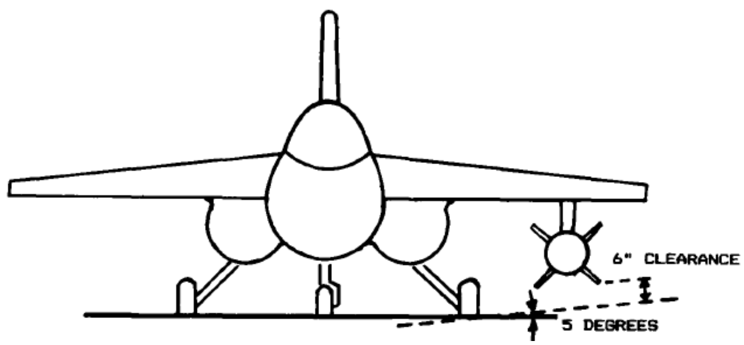

FIGURE 7: Mid Wing Design [11]

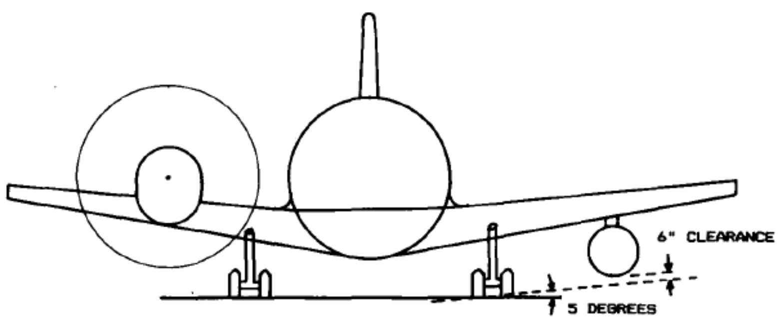

FIGURE 8: Low Wing Design [11]

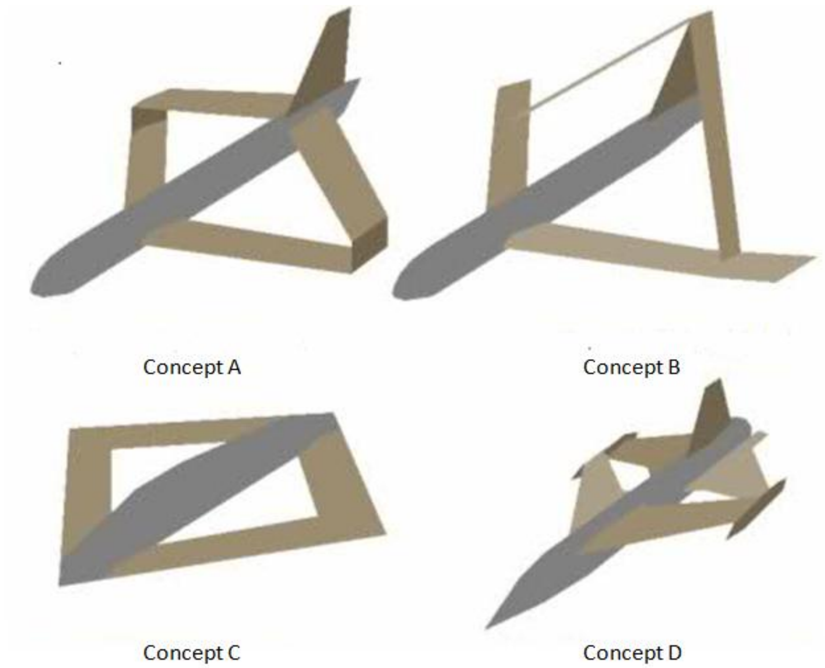

FIGURE 9: Advanced Joined Wings Concepts [9]

As shown in figure 9 above, concept A is a typical box wing configuration. Concept B is a typical joined wing configuration. Concept C is Boeing's fluid wing configuration. Concept D is the D0014's bi-diamond wing configuration.

3.2.2 Airfoil Design Alternatives

The airfoil design characteristics will affect the lift versus the drag coefficients. The highest possible lift to drag ratio is a main objective when designing an airfoil. Designing and validating the results of a custom airfoil can be very rewarding both in the knowledge gained as well as in the achieved performance. Therefore, designing our own airfoil was originally considered by the team. However, as the research and the amount of effort required for such an endeavor became better understood, it also became apparent that an entire thesis can be dedicated just to this one aspect of our design. Therefore, it was then decided to base our airfoil selection based on previous available studies and data.

3.3 Empennage Design Alternatives

The empennage of the airplane is an important consideration. There is a variety of empennage design variations that were researched and considered including the ones in the figure 10 below:

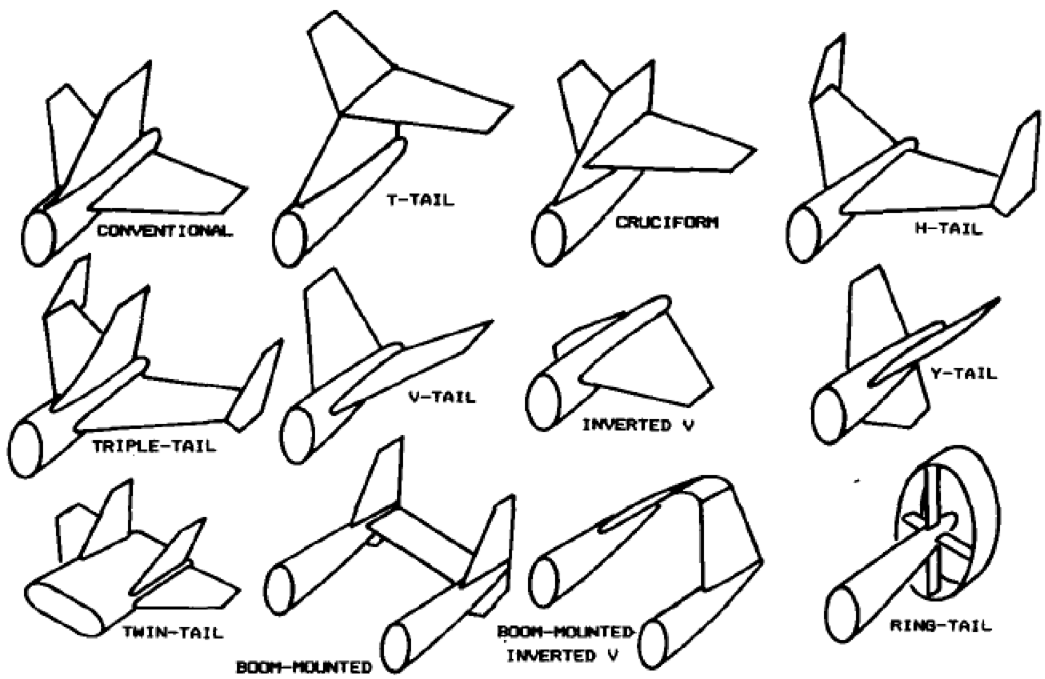

FIGURE 10: Empennage Variations [11]

The boom mounted tail and a conventional tail as shown in the figure above were both considered during our initial concept research. Even a variation of the ring tail together with a twin tail was originally considered when the team was following the original set of rules which required the use of an electric motor.

3.4 Engine and Propeller Alternatives

The team has discovered a number of available static and dynamic tests performed on some of the available engines using standard commercially available propellers. Once the research is completed, an engine and propeller combination will be selected using a matrix method similar to the one used for the airfoil selection.

The selected engine and propeller combination will then go through test to validate the expected results. The tests, results and final propeller selection are covered later in this report.

3.4.1 Engine Fuel Consumption

In order to determine the amount of fuel required for each competition trial, it is necessary to estimate the fuel consumption of the engine/propeller combination. This is also an important consideration in order to then select the appropriate capacity fuel tank.

TABLE 4: Approximate Fuel Consumption Rates for OS Engines [12]

Approximate Fuel Consumption Rates at Full Throttle for the Most Commonly Used Aircraft Engine Sizes

	2-Stroke Glow cu. in	4-Stroke Glow cu. in	2-Stroke Gas cc	4-Stroke Gas cc
0.375 oz/min				25
0.5 oz/min				32
0.75 oz/min	.32	.50	24	
1 oz/min	.40-.46	.70	32	
1.5 oz/min	.60	.90	50	
2 oz/min	.90	1.20	64	
2.5 oz/min	1.20	1.60		
3 oz/min	1.60	2.00		
3.5 oz/min	2.00			

Note that exact consumption rates will vary depending on the fuel:air mixture, type of fuel used, nitro content, prop size, rpm, condition of the engine and atmospheric conditions.

.5 Fuel System

The team estimated that the aircraft will need to perform for about 2 minutes, and based on the previously discussed fuel consumption rate, would require about 3 oz of fuel. However, in order to allow for possibly having to do a “go around,” it is deemed that at least twice that amount should be available. Given the fact that the aircraft needs to be as light and small as possible, it is necessary to select a tank that will hold just enough fuel for the performance. Below is an example of a fuel tank that would meet our previously stated criteria:

FIGURE 11: Fuel Tank [13]

The fuel tank above is an 8 oz capacity fuel tank made by Sullivan. The specifications for our tank are:

- Capacity: 6oz
- Height: 1.75 inch
- Width: 2.125 inch
- Length: 4 inch

3.6 Flight Control Systems

Flight control systems include the flight control surfaces (ailerons, elevator and rudder) as well as their mechanical and electrical requirements and arrangements. A thorough analysis of aerodynamic principles, force and torque requirements as well as the required electrical power was accomplished.

These calculations had to be done prior to purchasing the servos required to operate the flight control surfaces in order to make sure that the chose servos provided the necessary torque requirements.

3.7 Electrical Systems

The electrical system includes the on-board batteries, the batteries monitoring system, the remote control receiver, the electric servos and all the wiring and connections. This system was designed to be integrated into the finalized aircraft design.

After calculating the load requirements on the servos, it was then also required to chose a corresponding on board electrical power system capable or delivering the necessary voltage and power requirements to them.

3.8 Landing Gear System

The landing gear system was greatly influenced by the finalized aircraft design. Below were various alternatives for landing gear system arrangements:

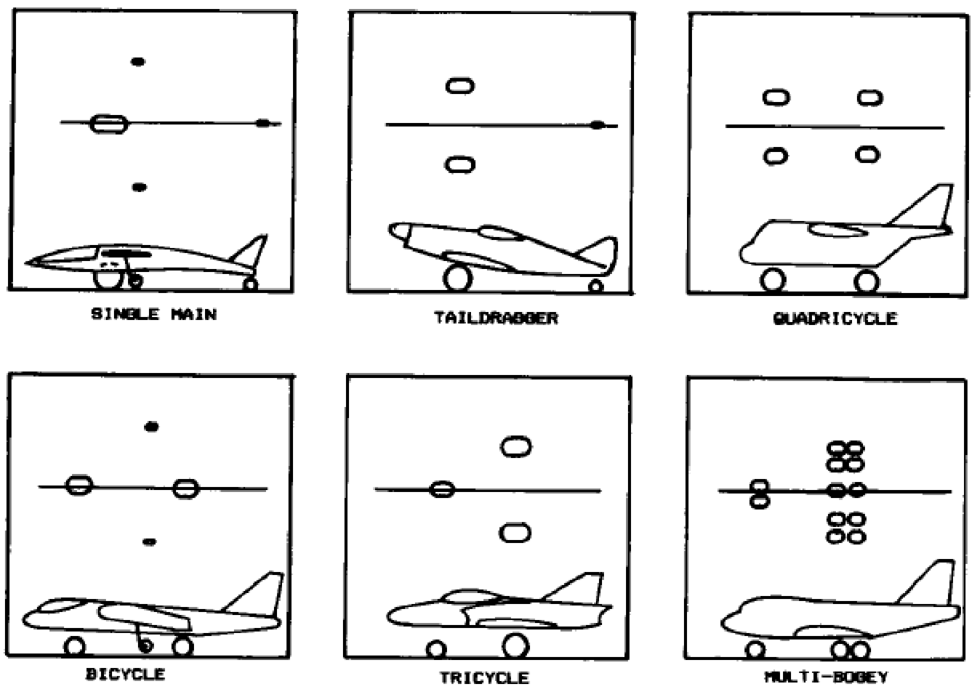

FIGURE 12: Landing Gear Arrangements [11]

3.9 Other Alternatives

As the prototype evolved, many components and alternatives had to be considered. For example, the necessary diameter of the wheels and tires had to be calculated depending on the chosen diameter of the propeller to make sure that adequate clearance was maintained.

3.10 Feasibility Assessment

Due to the fact that the competition is in Brazil, and that it was originally thought by the team that it might be necessary to rely on obtaining the services of a local remote control airplane pilot, the stability of the design was deemed a high priority. Therefore, the *PanthAir Cargo* design needed to be relatively easy to fly in order to mitigate the risk of an accident. Had the competition been local, the risk of using a less stable, but more innovate design such as a box-wing design would have been more acceptable.

Another very important consideration was the manufacturability of a chosen design. Trade-off studies were performed to finalize many of the details. For example, it may be very difficult if not impossible to manufacture an airfoil profile that might have been deemed having the best aerodynamic characteristics. In which case, perhaps a replacement profile may be used that exhibits acceptable aerodynamic characteristics, but was deemed feasible to manufacture.

3.11 Proposed Designs

3.11.1 Prototype System Description

The main characteristics that have been selected include:

- Top mounted wing
- Front mounted engine with a “tractor” pulling propeller
- As small as possible fuselage “shade area”
- Conventional tail arrangement
- Tricycle landing gear arrangement

Below are our first two originally proposed concepts:

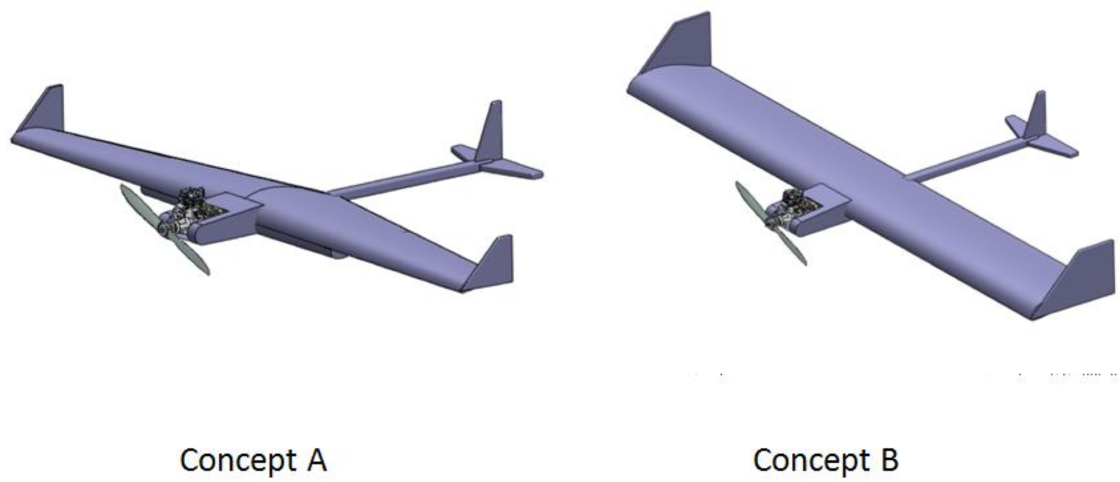

FIGURE 13: Proposed Concepts A and B

In Concept A above, the fuselage was widened to allow for cargo bay to be centrally and laterally located under the wing. In this method, the projected fuselage area was minimized. Access to the payload would be through a side door under the wing. This concept would allow for the use of tapered wings.

In Concept B above, the cargo bay was relocated to the inside of the wings which distributed the payload throughout the entire wing span. This concept was deemed more efficient at allowing the engine propeller thrust to be less obstructed compared to Concept A. It would not be possible to use tapered wings on this concept since the payload is evenly spread. Therefore, a rectangular wing would be necessary, and due to the larger surface area of the wing, a reduced wing span would be necessary.

The team had originally expected to use a "tail-dragger" landing gear, but later decided to use a tricycle landing gear arrangement. By doing so, the aircraft would have greater stability during landing and takeoff if a cross wind is present.

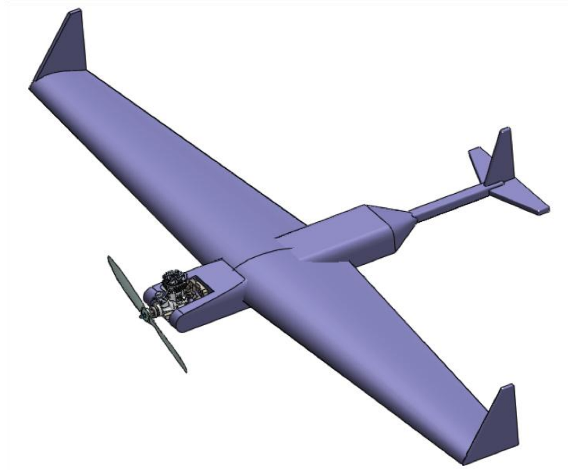

FIGURE 14: Proposed Concept C

Figure 14 above shows an illustration of our proposed Concept C. It was drawn to scale as evidenced by what appears to be a tail that is too small relative to the rest of the airplane. It uses a conventional high wing arrangement. In this concept, the cargo bay would be placed longitudinally in the fuselage. Access to replace the payload would be by removing the wing or through an access door in the back of the fuselage. This arrangement would slightly reduce the overall surface area available for the wing due to increased amount of projected area by the fuselage.

After more detailed analysis was done on concept C, the boom for the empennage was deemed as being too complex to attach to the fuselage. Concerns over accurate alignment, lack of space for installing servos, access to the cargo bay, weight, manufacturability and even reliability eventually caused concept C to be modified with a more conventional tail. Additionally, in order to have better access to the payload compartment, it was deemed that the best way was going to be from above by having a removable high wing installed. These modifications to concept C led to our final design Concept D which is shown in Figure 15.

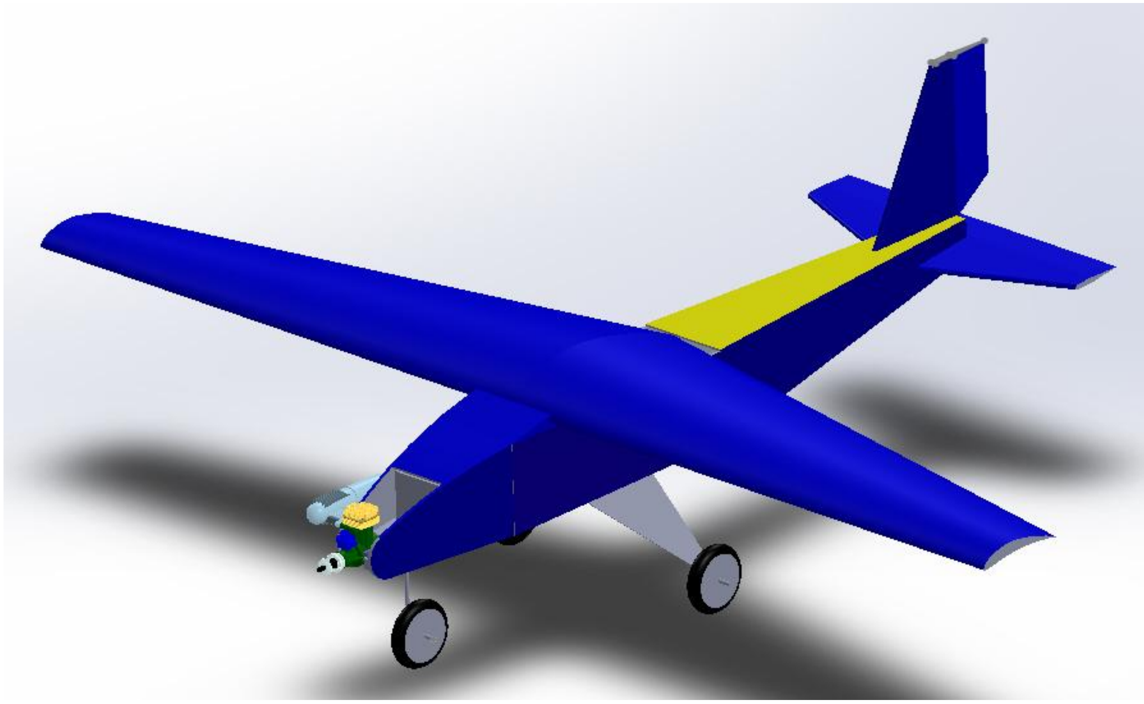

FIGURE 15: Final Design Concept D

Winglets are not shown in our final design above because they were not deemed beneficial for our design requirements. It was determined that the potential gains in lift were offset by a much higher increase in parasitic drag.

3.11.2 Prototype Structural Design

The team invested a great deal of time on structural design and analysis of concept B until it became apparent that it wasn't feasible. More details on these analyses are found later on in this report.

3.11.3 Proposed Wing Airfoil Design

Airfoils that were considered:

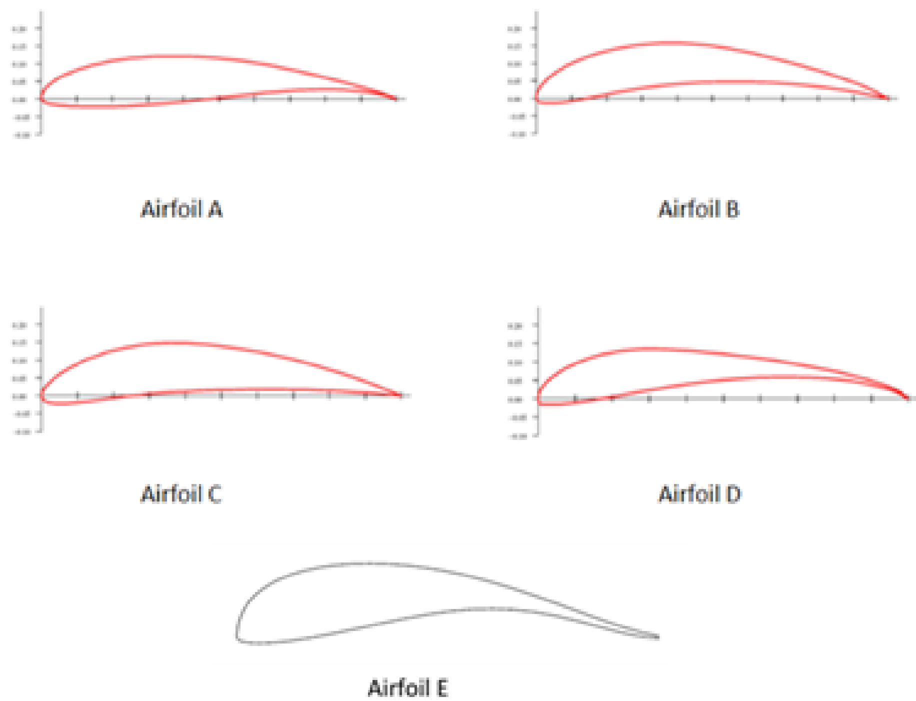

FIGURE 16: Airfoil Shapes [14]

Airfoil A is the Wortmann FX 63-137, airfoil B is the Eppler 423, airfoil C is the NACA 8414 and D is the Selig 1223. Airfoil E is the Reddy-LR-007, its a custom-made airfoil created by a student at FIU and optimized for low Reynolds numbers.

An objective method of selecting the design airfoil was deemed necessary since there were various criteria to consider. For example, it is desired to have the best possible aerodynamic performance that would give the best lift to drag ratio. However, there are trade-offs to consider. The best performing airfoils have extremely thin trailing edges that would potentially create areas that may be weaker or more susceptible to damage. These very long thin trailing edges are also deemed very difficult to manufacture especially given the limited recourses available.

The five proposed airfoil designs were evaluated on their aerodynamic performance, strength, and manufacturability. The results of this assessment are shown in following table:

TABLE 5: Airfoil Criteria Ratings

Airfoils	Airfoil Criteria Ratings Excellent = 5, Very good = 4, Good = 3, Fair = 2, Poor = 1		
	Aero Performance	**Strength**	**Manufacturability**
Wortmann FX 63-137	3	3	2
Eppler 423 Airfoil	4	4	4
NACA 8414 Airfoil	2	4	5
Selig 1223 Airfoil	5	2	1
FIU Custom Airfoil	5	2	1

After this initial assessment, the values obtained from the Table 5 above were used to calculate weighted relative ratings as shown in Table 6. By using this method, the airfoil with the highest rating ratio would be deemed the best choice given our selection criteria.

The Reddy-LR-007 and the Selig 1223 were deemed the best as far as the predicted aerodynamic performance. However, these two airfoils have very long and thin trailing edges that would be extremely difficult to manufacture compared to the other airfoils. These long and thin trailing edges are also susceptible to damage, so they would require special structural considerations. Because of these two concerns, these two airfoils were rated low in the manufacturability and structural integrity categories. As the team's research evolved, these concerns were deemed to be quite valid.

TABLE 6: Airfoil Selection

Airfoils	Relative rating number - R (=rating number x weighting factor)			ΣR	Σr	ΣR/r
	Aero Dynamic Performance	Strength	Manufacturability			
	3	1	3	30.00	6	
Wortmann FX 63-137	9	3	6	18.00	6	3.00
Eppler 423 Airfoil	12	4	12	28.00	6	**4.67**
NACA 8414 Airfoil	6	4	15	25.00	6	4.17
Selig 1223 Airfoil	15	2	3	20.00	6	3.33
FIU Custom Airfoil	15	2	3	20.00	6	3.33

The team was expecting the custom Reddy-LR-007 to be the best choice given the high performance expected; however, once it was analyzed using all the criteria above, it was not going to be the best choice. According to the table above, the best choice would be the Eppler 423 airfoil. As such, our team decided to accept the objective results, and use the Eppler 423 airfoil. This airfoil has a lot of camber which greatly contributes to its high lift low drag aerodynamic qualities. It is not an easy airfoil and wing to manufacture mainly due to the somewhat thin trailing edge.

The best performing airfoils scored low mainly due to their rather complex manufacturing requirements as well as being prone to damage because of their extremely thin trailing edges.

3.12 Analysis of Concepts

The team had ruled out concept A due to the very high aerodynamic frontal surface area obstructing the thrust generated by the engine and propeller. By obstructing the path of the thrust, the airspeed of the aircraft would be reduced which would be accompanied by a loss of lift.

Concept B has encountered some very challenging engineering stress concerns in having to carry the payload in the wings in a very limited space. In order to make this concept work, the displacement of the wing would have to be minimal to as to not place a load on the payload being carried. Simulations were run using various materials and various loads to determine if this was a feasible concept. The simulations included pulling 5 G's during flight, as well as just over minus 2 G's simulating a hard landing.

The results of these simulations are shown below:

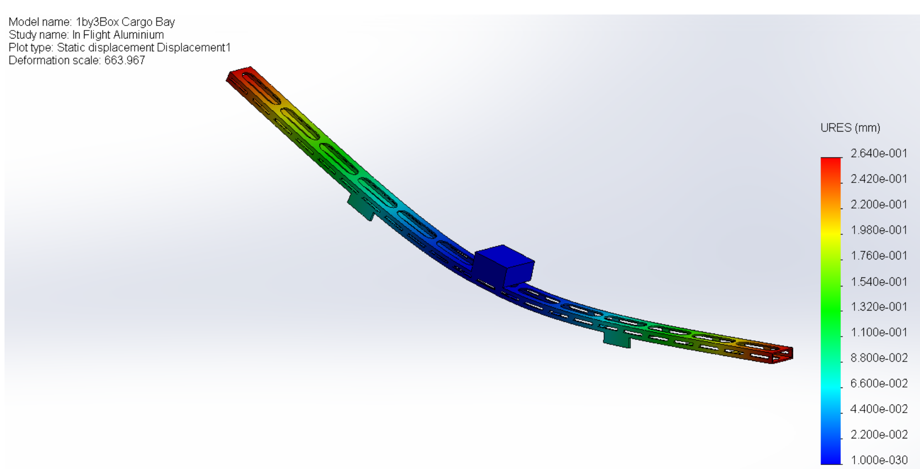

FIGURE 17: In Flight Displacement of Cargo Bay for Concept B

As seen in the figure above, the in-flight displacement at 5Gs would be about 1.04 inch at the wing tips. In this arrangement, a rectangular channel made out of 6061 aluminum alloy was used for the simulation.

Another simulation was also performed simulating a “hard landing.” In this simulation, a hard landing was assumed to take place if the aircraft was dropped from a height of 3 feet.

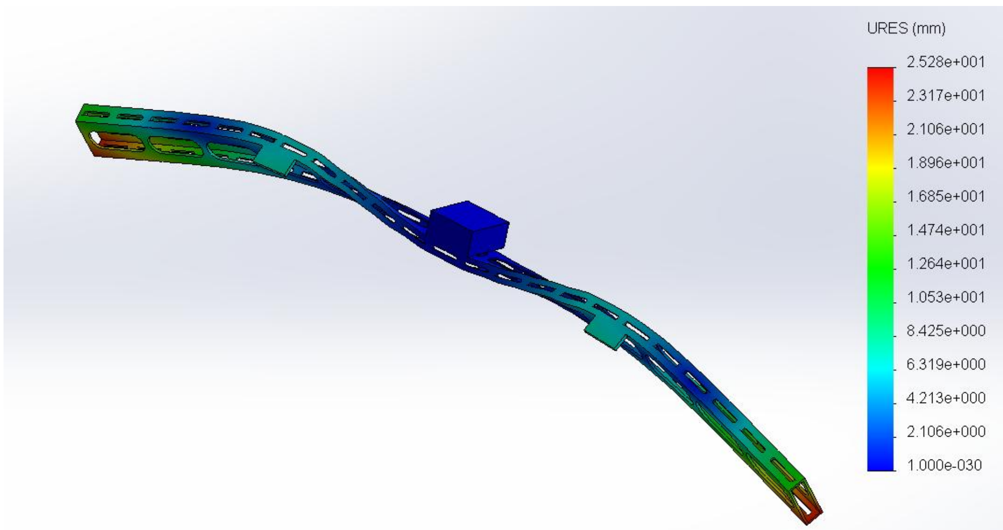

FIGURE 18: Hard Landing Simulation of Cargo Bay for Concept B

As seen in figure 18 above, a hard landing may cause a displacement of 0.99 inch.

As demonstrated in the 5 G and hard landing simulation, the cargo bay would require a more rigid structure which would have added undesirable weight to the aircraft.

Another concern with the design of concept B was that it would be very difficult to make the wing of this concept able to be separated into two or three pieces for shipping. Having a solid wing this size would have added hundreds of dollars to the cost of our project. Because of these concerns, concept B was also eliminated from any further consideration.

As a result of the analysis of concepts A and B, those two concepts were dropped from consideration. As explained in 3.11.1, Concept C evolved into our final design Concept D which was deemed relatively simpler and more reliable than the previous three concepts. The fuselage size was lengthened enough to accommodate the cargo bay. The empennage was changed to a continuation of the fuselage in order to allow for space for servos to be installed plus for a much simpler and smoother configuration. This final design did increase our empennage planform area, but said reduction only reduced our wingspan by about 2%.

Structural analysis of the completed wing and fuselage for Concept D has proven to be almost impossible to accurately model and to perform simulations on. The primary reasons are the fact that so many variables are unknown. For example, the exact adhesive strength of the various adhesives used, the different types of woods that were glued together (i.e. spruce, birch, balsa and plywood), the grain directions of different layers of plywood, etc. Even the moisture content in the air affects the wood as far as flexibility and strength. Had we used better scientifically defined materials and attaching methods such as aluminum being bolted together, said simulations would have been quite possible. However, metals would have added a lot of undesirable weight to our aircraft.

The team decided to build the aircraft wing based time proven conventional methods and materials. The ribs were made out of balsa except for a few in high stress locations which were made out using light-ply. The spars were made using spruce wood. Balsa was also used for spar webbing. The wing was covered with a thin layer of balsa which is also referred to as planking. Some areas of the wing were not covered with balsa and were covered with a see-through layer of aircraft plastic skin to allow for inspection of the internal construction of the wing. It is deemed that the planking also contributes to the structural integrity of the wing.

In order to mitigate the risk of wing and/or fuselage failure due to flight loads, it was decided to add external aluminum wing struts. If and/or when adequate internal wing strength is ascertained, these external load bearing struts can and will be removed. The struts themselves are made out of very light material to minimize weight. They are attached directly to the landing gear under the cargo bay and to a plywood rib that had been previously and intentionally placed into the wing instead of a balsa rib at a predetermined location just for this requirement. They are designed to be quickly connected and disconnected using a quite unique and innovative method that requires no tools. The specifics of the struts and the attachments are deemed proprietary due to the great potential competitive advantage that they offer. Therefore, in order to keep this as an FIU advantage in present and future competitions, said details will not be published in this report.

3.13 Final Design

After carefully considering the proposed designs and weighing the pros and cons for each one, the team opted for concept D. Although not as innovative as concepts A, B and C, concept D was considered to be the best one for meeting our requirements.

PanthAir Cargo's initial design process placed emphasis on the following characteristics:

1. Cost of design
2. Stability of the design
3. Manufacturability of the design
4. Structural Integrity of the design
5. Performance of the design

The reason that performance was placed at the bottom was due to the fact that if any of the previous priorities are not met, performance would not affect the project. Secondly, it is deemed that an experienced pilot in a relatively less capable but stable design will out-perform a less experienced pilot flying a more sophisticated aircraft design.

3.13.1 Aircraft Sizing

As previously explained, our aircraft planform area was limited by the rules. Naturally, it would be advantageous to use as much of the available planform area for the wing in order to generate the highest possible lift.

In order to determine the maximum area available for the wing, a series of iterations and calculations were done using a spreadsheet. Everything that contributed to the planform area was either calculated or estimated at first. These included the areas of the forward fuselage, empennage, engine compartment and engine exhaust. After all of these were reduced from the maximum available area, the remaining area was split 85%/15% between the wing and the horizontal tail respectively.

A big driver for the fuselage size and width was the chosen cargo bay configuration while still achieving the previously stated required minimum volume. It was deemed cost beneficial to make our cargo bay capable of carrying a payload carrier carrying standard width size steel plates. An initial assumption was based on research of previous competition results that perhaps as much as 30 pounds of payload might be possible. Therefore, it was needed to find a combination that would allow for that much payload to be carried while taking into consideration many factors including the fact that it was needed to place the center of gravity of the payload carrier right on the center of gravity of the aircraft.

Tradeoff analysis was done between the length, width and height of the payload carrier and cargo bay so as to have minimal protrusion from outside of the wing while at the same time being large enough to allow for the maximum possible payload weight capability. The final chosen cargo bay size was 18.5 inches long x 4.125 inches wide x 4 inches high, and the payload carrier to be 10 inches long x 4 inches wide x 4inches high.

The width of the cargo bay dictated the required width at the front of the empennage. The width of the tip of the empennage was chosen based on balancing the desire to have it be as thin as possible with the necessity to have enough support for the horizontal and vertical tail plus space for control linkages. The length of the empennage was chosen mainly based on the need for flight stability. This stability is obtained by applying the Tail Volume Coefficient Method.

In order to use the Tail Volume Coefficient Method to estimate the required empennage length, it is necessary to indentify the variables and dimensions shown in Figure 19 below:

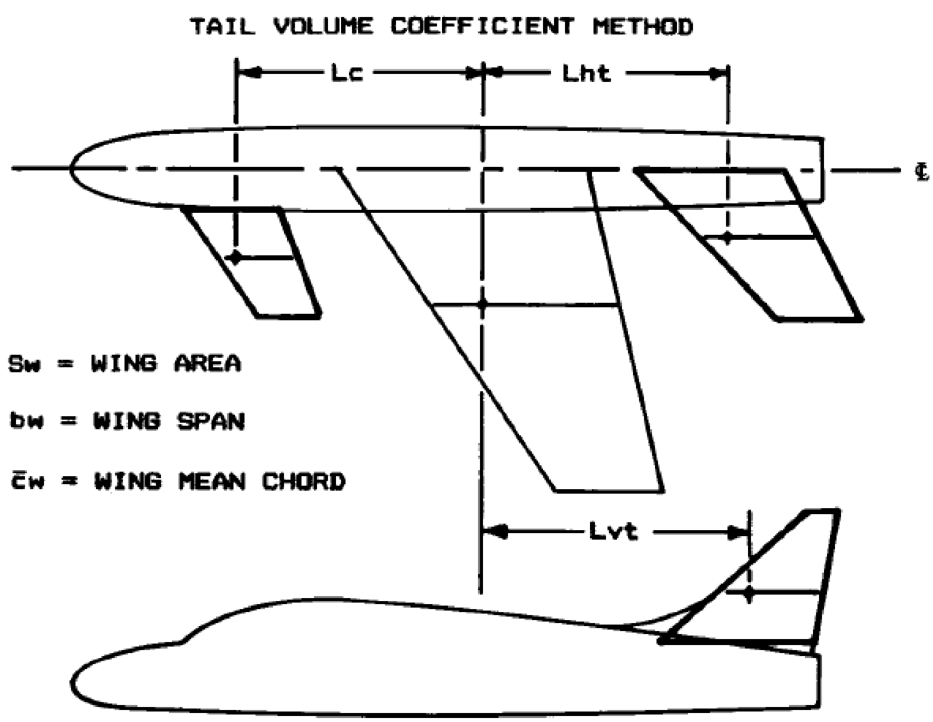

FIGURE 19: Tail Volume Coefficient Method [11]

The tail volume coefficient for the vertical tail c_{Vt} is:

$$c_{Vt} = \frac{L_{Vt} \times S_{Vt}}{b_w \times S_w} \tag{1}$$

The tail volume coefficient for the horizontal tail c_{Ht} is:

$$c_{Ht} = \frac{L_{Ht} \times S_{Ht}}{\overline{C}_w \times S_w} \tag{2}$$

The moment arms L_{Vt} and L_{Ht} are commonly approximated as the distances from the 25% of wing mean chord length to the tail quarter chord length of the vertical tail and horizontal tail respectively. Determining the mean chord length is covered in detail in the next section. The surface areas for the wing, horizontal and vertical tail are denoted by S_w, S_{Ht} and S_{Vt} respectively. The wingspan is denoted by b_w.

Typical values for c_{Ht} are 0.2 to 0.7, and typical values for c_{Vt} are 0.02 to 0.07. The higher the number, more stability is achieved. We chose to go with a c_{Ht} of 0.5 and a c_{Vt} of 0.04. By re arranging equations 1 and 2, and by selecting a suitable tail volume coefficient, the minimum required empennage length can be calculated.

3.13.2 Wing Geometry

The shape and size of the wings are key characteristics affecting the performance of the aircraft. In Figure 20 illustrates some of the terms and variables associated with defining our wing geometry.

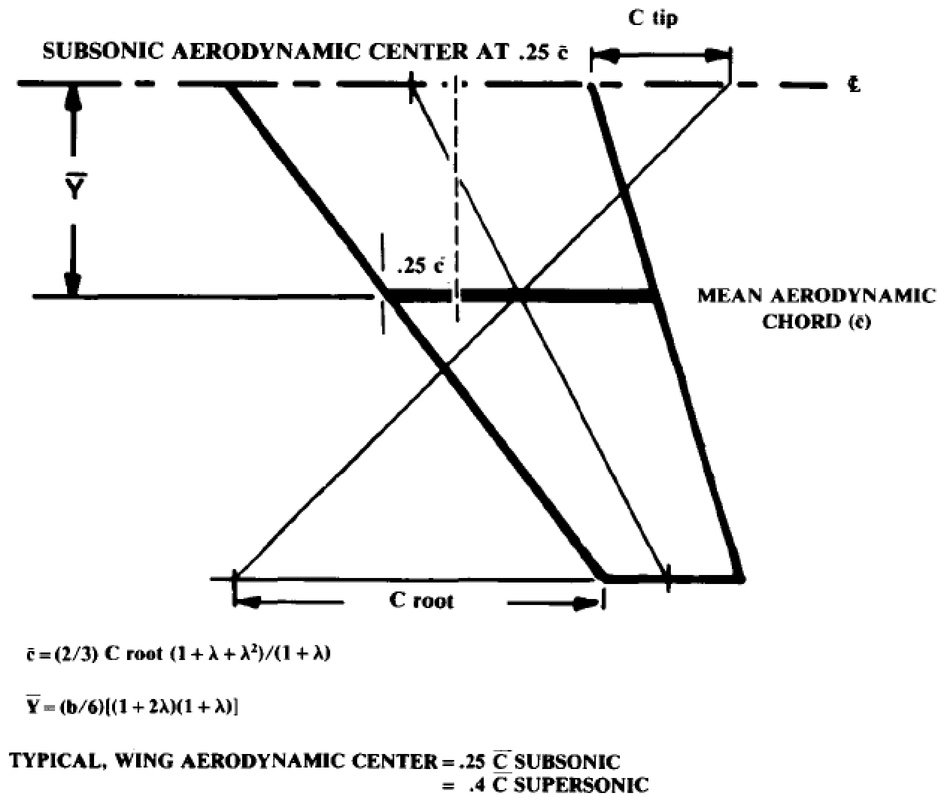

FIGURE 20: Wing Mean Aerodynamic Chord (MAC) [11]

The formula for calculating the MAC or average wing chord $\bar{C}_w$ was obtained from the previous figure and is shown below:

$$\mathrm{MAC} = \frac{\frac{2}{3} \times \bar{C}_w \times \sqrt{(1+\lambda+\lambda^2)}}{(1+\lambda)} \quad (3)$$

In the formula above, λ stands for the taper ratio of the wing. Taper affects the distribution of lift along the span of the wing and the optimal condition is achieved when the wing takes an elliptical shape. An elliptical wing shape minimizes drag due to lift, or “induced” drag. An elliptical wing compared to a non-twisted rectangular wing can reduce drag by as much as 7% [11].

Unfortunately, an elliptical shape is usually more difficult to manufacture, so wings are generally tapered instead. A taper ratio (Croot/Ctip) of 0.45 produces a lift distribution very close to an elliptical wing with a drag due to lift less than 1% [11]. This taper ratio was chosen for our wing design.

The location of the MAC or average wing chord $\bar{C}_w$ is referred to as $\bar{Y}$ and is calculated as follows:

$$\bar{Y} = \left(\frac{b}{6}\right) \times \left((1 + 2\lambda)/(1 + \lambda)\right) \tag{4}$$

The taper ratio and other variables affecting wing geometry are shown in Figure 21 below:

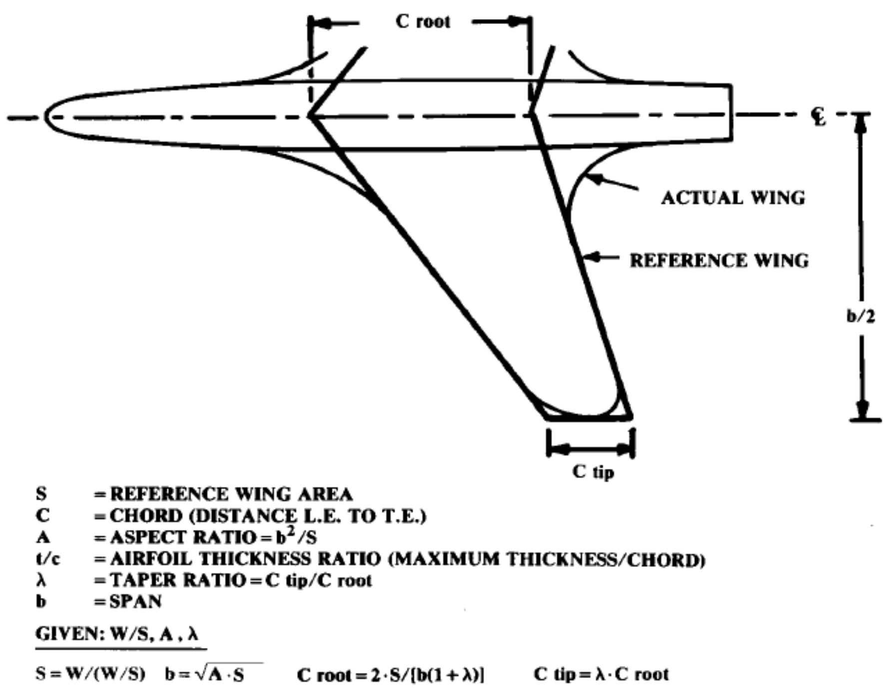

FIGURE 21: Wing Geometry [11]

Aspect Ratio

Another very important factor affecting wing geometry and performance is the Aspect Ratio (A). The aspect ratio is defined as the span squared divided by the area:

$$A = \frac{b_w^2}{S_w} \tag{5}$$

Generally, the high pressure beneath the wing tries to escape into the lower pressure above the wing near the wing tips. This is also referred to creating tip vortices. A wing with a higher wing span and thus higher aspect ratio helps to reduce this effect. A statistical method was used to select an appropriate aspect ratio. A value of 7.6 is a typical value for single engine general aviation airplanes [11], and it was deemed the appropriate choice for our design.

The horizontal tail is not designed to create lift and an appropriate value for its aspect ratio should be between 3 and 5, so 4 was deemed a good choice. Similarly an aspect ratio for the vertical tail should be between 1.3 and 2, and 1.5 was deemed an appropriate choice for our design.

One the aspect and taper ratios were selected, they were used in conjunction with the calculated available wing area to determine the resulting shape and size.

Wing Incidence

The angle formed between the chord line of the wing and the longitudinal axle of the fuselage is referred to as the wing angle of incidence. Normally, the fuselage and wing should complement each other to optimize lift and minimize drag. Normally, the optimum angle can be estimated through CFD or wind tunnel testing. Transport aircraft generally use a 1% angle of incidence, and our team went with a 0% angle of incidence.

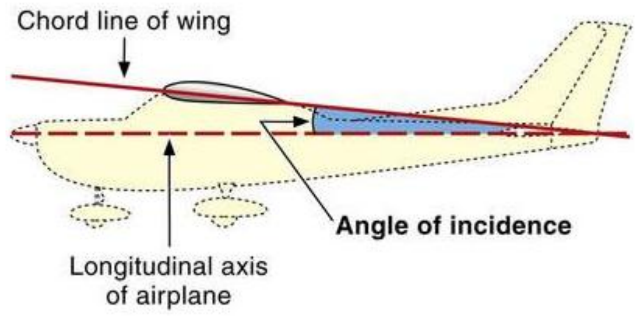

FIGURE 22: Angle of Incidence [15]

Similarly, the horizontal tail also has an angle of incidence. However, the primary purpose of the horizontal tail is to balance the pitching moment of the wing, so a negative angle of incidence of 3 degrees was applied to our aircraft.

<u>Dihedral Angle</u>

The angle of the wing in respect with the angle of the horizontal as viewed from the front is referred to as the dihedral angle of the wing. Generally, adding a positive dihedral angle will help an aircraft maintain stability along the longitudinal axis. A small loss of lift accompanies a positive angle of lift due to the air high pressure air slipping outward toward the wingtips. A dihedral angle may also place a sharp concentration point for stresses and therefore, requires careful engineering. An example of a positive dihedral angle is shown in Figure 23 below:

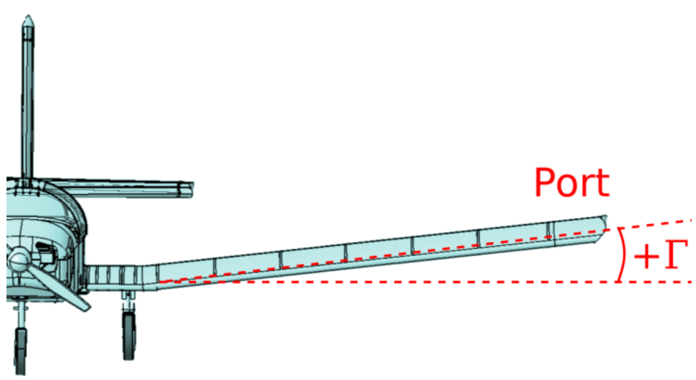

FIGURE 23: Dihedral Angle [8]

After carefully considering the advantages and disadvantages of using some positive dihedral angle, it was decided that no dihedral angle would be most appropriate for our application.

Wing Sweep

The wing sweep angle is the angle formed between the wing's quarter chord and an angle that is 90 degrees to the centerline of the fuselage. Sweeping the wings slightly aft may help stability the same as positive dihedral, and sweeping them forward similarly to negative dihedral. Positive dihedral is required on supersonic aircraft due to the creation of a shock cone. However, it is not necessary for slow subsonic aircraft. The following figure depicts the three basic types of wing sweep angles.

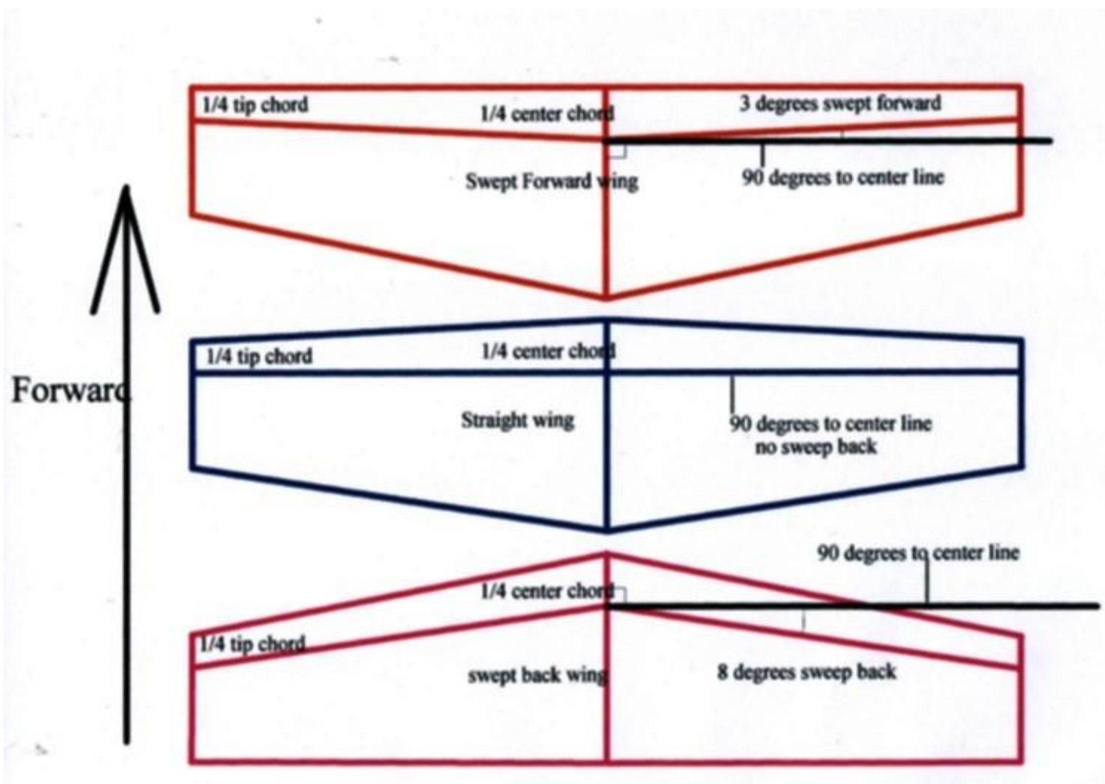

FIGURE 24: Wing Sweep [16]

A forward swept swing as shown at the top Figure 24 was chosen for our final design. It was deemed that this configuration would provide favorable flight and lift characteristics as well as providing for a strong uninterrupted spar at around the 25% chord length which is where we wanted to place our center of gravity (CG).

Wing Twist

Wing twist is used to prevent the loss of control of an aircraft as the wing approaches a stall angle. Twist angle is sometimes referred to as "washout." The twist angle is the difference of angle of incidence between the tip chord and the root chord. Generally, a washout of as much as 5 degrees is used. Although this is a desirable characteristic, it was deemed that it was going to complicate the manufacturing process of our wing, so the angle of twist used for our design was left at 0 or no twist angle.

3.13.3 Control Surface Sizing

Aileron Sizing

The sizing of the span of the ailerons was done using a statistical historical approach. By using this method an aileron should start at around the 50% of the wing span and extend outward to 90%. Ailerons are not deemed very effective at the tip due to vortices, but in order to keep our wing as simple as possible to manufacture, the ailerons continued to the wing tips.

A similar approach was done for calculating the chord length of the ailerons. Typically the aileron chord length should be between 15-25% of the chord. In order to minimize the structural complexity of the wing and aileron for our design, a constant aileron chord was used, and it was based on using 20% of the MAC.

<u>Evevator Sizing</u>

The chosen span for the elevator was the entire span of the horizontal tail. The chord length of the elevator is typically 25-50% of the horizontal tail chord. Just like the ailerons, it was deemed appropriate to use a constant chord for the elevator, and our selected elevator chord length was based on 40% of the average chord length of the horizontal tail.

<u>Rudder Sizing</u>

The entire span of the vertical tail was used as the span for the rudder. The chord length of the rudder is typically 25-50% of the vertical tail chord. A constant rudder chord based on 40% of the average rudder chord was chosen for our design.

3.13.4 Servo Capacity Requirements

The flight control surfaces are operated by electrical servos which come in a variety of sizes and torque capacities. In order to determine the appropriate servo size, it was first necessary to determine the torque exerted by the flight control surface on the servo.

One of the main influences on the amount of force exerted on a flight control surface is the speed of the aircraft. Although our aircraft is only estimated to operate at around 40 MPH, a worst case scenario of 60 MPH was used simulating a dive condition.

The formula used to determine the required servo size is [17]:

$$Torque\ (oz - in) = 8.5^{-6} \times \frac{C^2 \times V^2 \times L \times \sin(S1) \times \tan(S2)}{\tan(S2)} \tag{6}$$

Where:

C = control surface chord in cm

L = control surface length in cm

V = speed in MPH

S1 = max control surface deflection in degrees

S2 = max servo deflection in degrees

There are some assumptions and conditions required for this formula to work including:

- The pushrods be longer than the servo and control horns
- Zero angle of incidence between the wing, fuselage, horizontal and vertical tail
- The control linkages have zero offset at hinge line and are perpendicular to horns at neutral position
- Negligible friction on control mechanisms and surfaces are mass-balanced

TABLE 7: Servo Sizing

	Control Surface Max Deflection from Center (degrees)	Servo Max Deflection from Center (degrees)	Max Speed (MPH)	Resulting Servo Torque (oz-in)	Torques plus 30% (oz-in)
Aileron	45	50	60	30.46	39.60
Rudder	45	45	60	21.09	27.42
Elevator	45	50	60	33.35	43.35

As shown in the table above, the resulting torque values were increased by 30% for safety reasons and because sometimes servos do not perform to their advertized capacities. These final torque values were used to select our flight control servos.

3.13.5 Landing Gear

It was deemed that the landing gear for the design be capable of handling the maximum amount of weight as set by the rules which is 20 kg or about 44 pounds. The team decided on using a tricycle landing gear arrangement. After considering a custom manufactured landing gear, it was deemed cheaper to purchase certain landing gear components from vendors including the nose landing gear strut, the main landing gear support as well as the wheels/tires and axles.

The nose landing gear that was purchased was a class 4 gear which uses a coiled steel wire size of 3/16 inch. The struts on this landing gear can be cut to a desired length to obtain the desired propeller clearance and is shown in the figure below:

FIGURE 25: Nose Landing Gear Stud

Similarly, it was determined that the main landing gear support be purchased from a vendor. A commercially available support was found made out of 1/8 inch thick 6061-T6 Aluminum. After running stress simulations on the support, it was deemed adequate for our requirements. A picture of the main landing gear support is shown below:

FIGURE 26: Main Landing Gear Support

Special attention was devoted to the location of the landing gear. It is desirable for directional tracking stability on the ground to have as long a wheel base as possible. It was also desired to minimize the amount of load on the nose landing gear so as to not over load it. Lastly, it was desirable to place the main landing gear as close as possible just behind the center of gravity to allow for the aircraft to achieve take off roll within the maximum take off distance allowed by the rules. Special consideration was given to making sure that the CG did not move behind the center of the main landing gear axles as the aircraft rotated. In fact, the main landing gear placement as well as the final placement of the wing was established as a result of numerous weight and balance tests to obtain a safe yet well performing combination. Figure 26 below is a picture taken during one such weight and balance test on the prototype:

FIRURE 27: Weight and Balance Testing

The wheel/tires that were selected were commercially available lightweight ones. The team experimented between a harder compound tire (little rolling resistance) and a soft tire compound (higher rolling resistance) to allow for the aircraft to stop within the required distance.

The softer tires were slowing the aircraft after landing as predicted, but were also adding to our take off distances. Therefore, the team looked for another solution and experimented adding a brake system to the nose landing gear. It was then decided that a brake system should be tried, so one was installed. The system was operated by attaching a cable to the elevator's servo. When placed in tension, it pulled and reduced the size of a coiled spring that surrounded a rotor that was connected to the nose landing gear wheel. The rotor was manufactured out of 6061 aluminum with pressed in steel inserts, and it was manufactured with the assistance of Mr. Zicarrelli of the FIU Manufacturing Lab. A picture of the installed brake is shown below:

FIGURE 28: Nose Landing Gear Brake

3.13.6 Propulsion System

Engine Selection

The engine for our design had to be selected from the list contained in the rules. The team wanted to use the OS 61 FX because of its outstanding dependabilty reputation, but it was no longer made nor available. An analysis was done on the remaining engines, and the Magnum XLS 61 was selected. The team hasn't been able find what the advertized horsepower is for this engine, and it was the heaviest of the available engines. However, it was relatively economical compared to the other available engines.

Engine Placement

In order to offset the torque produced by the engine/propeller during flight and the resultng tendency for the aircraft to roll left, the engine was mounted at 3 degrees to the right as shown in the figure below:

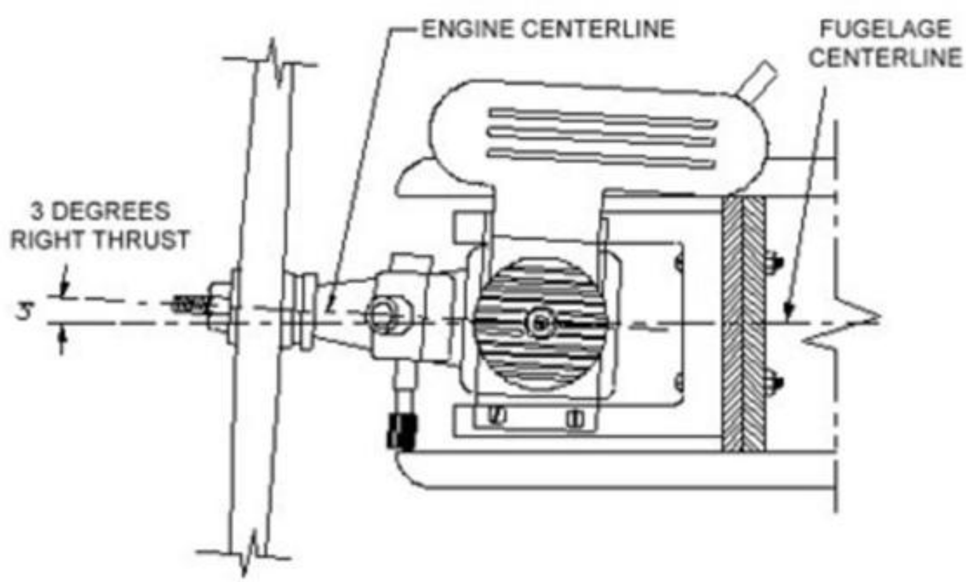

FIGURE 29: Engine Mounding [18]

Propeller Selection

Choosing the right propeller and engine combination was a very important decision that the team had to make. After selecting the engine, the team had to select a propeller that would produce the maximum possible thrust for our airplane. Choosing the right propeller for a given engine will allow the engine to operate at its optimal RPM, and produce good thrust results. A bad propeller choice will result in having an engine and propeller combination that will produce poor thrust results.

Propellers are nothing more than vertically mounted, rotating wings. These wings are twisted at a specific AOA. This twist is greater towards the axis of rotation because the rotational speed and therefore the thrust is greater at this part of the propeller. The tips of the propeller rotate at a much higher speed so their pitch has to change accordingly. Propellers come in different shapes and sizes, but the two most important numbers when choosing a propeller are its diameter and pitch. The diameter is the measure from tip to tip of the propeller. The pitch is a measure of how far the propeller will travel through the air per each rotation of the engine. The greater the pitch means the propeller will travel further per revolution.

When selecting a propeller, if a propeller with not enough diameter or pitch is selected, the engine RPMs will be high, but not necessarily the thrust. If a propeller with too much diameter or pitch is selected, the engine RPMs will bog down, and again the produced thrust will be low.

Engine manufacturers provide a range of suitable propellers for a given engine, and the team decided to use the manufacturer's suggested propeller of 11 X 7 (the first number being diameter, second number being pitch) to break-in the engine. Half a gallon of 10% nitro fuel was used to break-in the engine before any test flight was performed to ensure an optimal performance of the engine.

The engine manufacturer's suggested propellers included 11x7, 11x8, 12x5, 12x7 and 13x4 propellers. That provided us with one way of choosing a propeller. Another way to select the proper propeller is to follow the standards and recommendations for a propeller and engine size combinations as shown in the following chart:

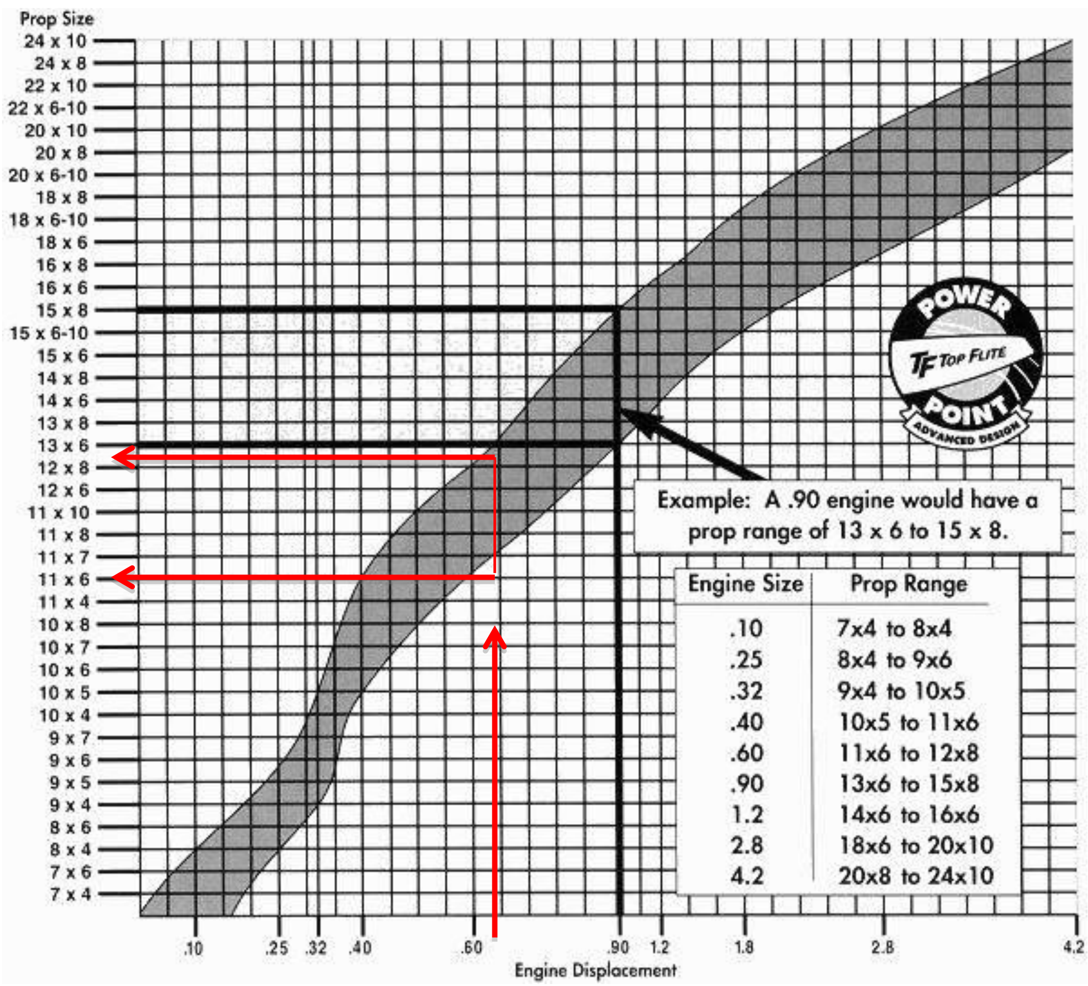

FIGURE 30: Propeller Selection Guide [19]

As the graph above shows, the recommended range for propeller sizes that match a 0.61 engine allowing it to operate at optimal RPM goes from 11x6 to 13x6.

The team conducted static thrust testing on various propellers to find out which propeller actually delivered the most amount of static thrust. The test was performed using a force gage attached to the rear of the aircraft, and the engine was operated at maximum throttle. The results of these tests are shown in Table 8 below:

TABLE 8: Static Thrust Test Results

	Propeller Size [diameter and pitch in inches]	Static Thrust [pounds force]	Measured RPM
Test 1	11 X 7	5.4	N/A
Test 2	12 X 7	6.3	N/A
Test 3	13 X 4	8.9	12,920
Test 4	13 X 7	7.7	10,250
Test 5	13 X 8	7.2	9750

An RPM gage was not available for the first two tests. Each propeller was tested three times, and the results were averaged and are shown in this table.

FIGURE 31: Propeller Static Thrust Test Setup

3.13.7 Final Prototype Pictures

The final prototype conducted successful test flights that proof the accuracy and feasibility of the conceptual designs. This prototype has been flown in multiple occasions without any accidents or mishaps. The next pictures were taken after its last test flight at Markham Park in Weston, Florida.

FIGURE 32: Final Prototype Front View

FIGURE 33: Final Prototype Top View

FIGURE 34: Final Prototype Side View

FIGURE 35: Final Prototype Top-Front View

4. Performance Analysis

4.1 Performance Analysis

Take off velocity V_{TO}

The required take off velocity V_{TO} is calculated using the following equation [20]:

$$V_{TO} = \left(\frac{2W}{S_{REF}\ \rho\ .8\ C_{Lmax}}\right)^{\frac{1}{2}} \quad (7)$$

Where: *W*= aircraft weight

P = air density

S_{REF} = wing surface area reference

C_{Lmax}= max coefficient of lift for the airfoil

Assuming a maximum weight of 44 pounds, sea level, S_{REF} = 861 in^2 (5.98 ft^2), and C_{Lmax} =1.85 for our airfoil, the required take off velocity would need to be 64.6 ft/sec or around 44 MPH.

The acceleration during takeoff may be calculated as follows [20]:

$$a = \left(\frac{g}{W}\right)[(T - D) - F_C(W - L)] \quad (8)$$

Where: g= gravitational constant= 32.2 ft/sec ^{2}

F_C= coefficient of rolling resistance = 0.03 (typical for heavy RC plane)

T= thrust

D= drag force

W= aircraft weight

L= lift

The acceleration will vary during takeoff. The aerodynamic drag will increase with lift accompanied by a decrease in rolling resistance. The available thrust will also decrease as the velocity of the aircraft increases.

As shown in the previous section, the available maximum static thrust was determined. The available dynamic thrust is estimated based on the velocity of the aircraft by using the following chart which is based on statistical data for RC planes.

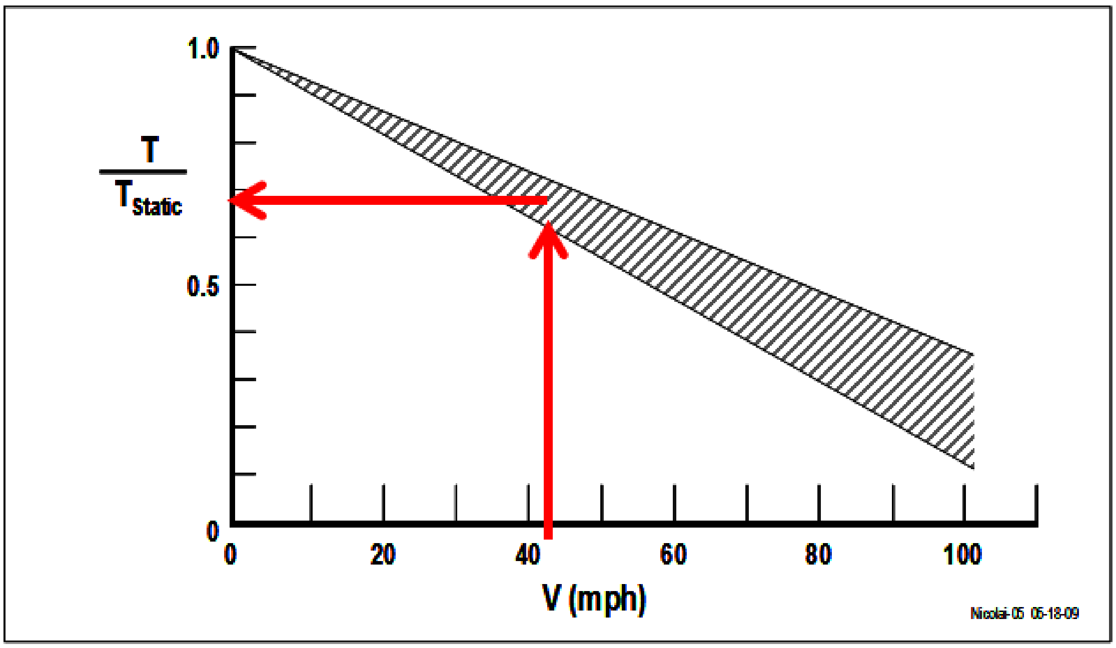

FIGURE 36: Dynamic Thurst Estimation [20]

Based on the figure above, at our desired V_{TO}, the available thrust is about .7 of the static thrust.

The drag force F_D is calculated using the following equation:

$$F_D = \rho V^2 C_D S_{REF} \tag{9}$$

Where the C_D is calculated according to equation (15) found later in this section.

The maximum allowed takeoff distance is 200 feet, but it is deemed necessary to have the takeoff ground roll distance, S_{GR}, be no greater than 175 feet in order to for the aircraft to takeoff by the 200 feet mark. The following equation may be used to calculate the required average acceleration:

$$S_{GR} = \frac{V_{TO}^2}{2\,a_{mean}} \tag{10}$$

Reynolds Number

The Reynolds Numbers (Re) calculations were a fundamental requirement for our performance analysis, and will vary depending on the velocity of the aircraft. The formula for Re is as follows:

$$Re = \frac{\rho V L}{\mu} \tag{11}$$

Where: ρ = density (slugs/ft^3)

V = velocity (ft/sec)

L = character length (feet)

μ = viscosity coefficient (slugs/ft-sec)

Aerodynamic Coefficients

The lift and drag forces are generally treated as non-dimensional coefficients and are shown in the equations below:

Lift force $L = qSC_L$ (12)

Drag force $D = qSC_D$ (13)

Where S= wing reference area S_{ref}

C_L= coefficient of lift

C_D = coefficient of drag

q = the dynamic pressure of the free stream air and is defined by:

$$q = \frac{1}{2} \rho V^2 \quad (14)$$

For a cambered wing such as the one on our aircraft, the C_D is calculated using the following equation:

$$C_D = C_{Dmin} + K' C_L^2 + K" (C_L - C_{Lmin})^2 \quad (15)$$

Where: C_{Dmin} is caused by skin friction drag from all the surfaces

K' is the induced factor and is calculated using the following equation:

$$K' = \frac{1}{\pi ARe} \quad (16)$$

Where e for low speed, low sweep wings is typically 0.9- 0.95

K'' is the viscous factor function factor. It can be very difficult to estimate. It can be estimated using the slope of the C_D vs $(C_L\text{-}C_{Lmin})^2$ for the airfoil at a specified Re number. For example, at Re = 3.78 E05, which corresponds to the aircraft traveling between 40 and 50 MPH the K" is the slope of the line in the following graph:

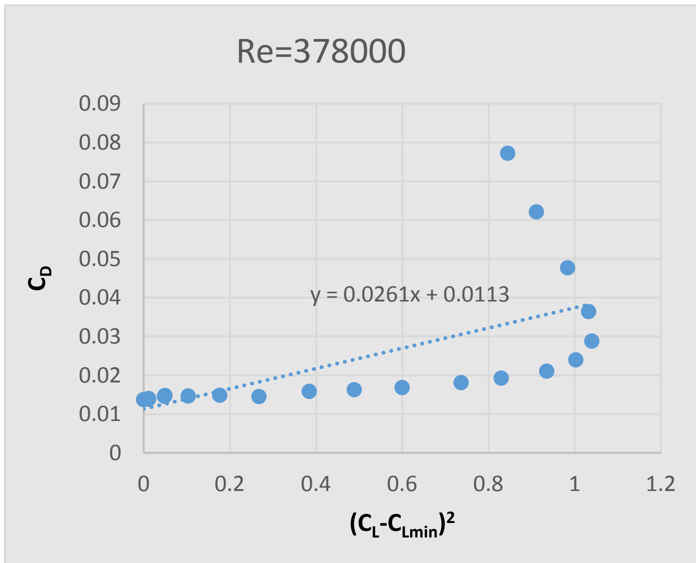

FIGURE 37: CD vs $(C_L\text{-}C_{Lmin})^2$ Graph

The slope of the trend line in the graph above is 0.0261 which is then used as the K" factor for calculations using Re = 3.79 E05.

A very lengthy calculation process is required to calculate the values for C_{Lmin} at various velocities. Each part of the aircraft contributes to this number including the landing gear. The calculations and explanations on how to arrive at the C_{Lmin} will be included in the next report.

In order for the aircraft to accelerate and maintain the necessary velocity to maintain stable flight, the F_{thrust} must be equal to or greater than the sum of all the opposing forces $\sum F_{opposing}$. The opposing forces are made up by the force necessary to accelerate the mass F_{accel}, the force caused by the wheels friction F_{friction}, and the force caused by wind resistance F_{drag}. Or:

$$F_{\text{thrust}} = \sum F_{\text{opposing}} = F_{\text{friction}} + F_{\text{accel}} + F_{\text{drag}} \tag{17}$$

Using formulas 2 and 8 along with the calculated drag coefficients, the predicted take off distances in the table below were calculated. These calculations included the prevailing 5 MPH head wind at the field.

TABLE 9: Calculated Take off Distances

Theoretical Takeoff Distance Given Static Thrust	1st test	2nd and 3rd tests	4th test	5th test	6th test	7th test
Payload	9.80	14.20	16.30	17.80	18.40	20.10
Total Aircraft Weight (lb)	21.74	26.14	28.24	29.74	30.34	31.87
Headwind (mph)	5.00	5.00	5.00	5.00	5.00	5.00
Headwind (ft/s)	7.33	7.33	7.33	7.33	7.33	7.33
Calculated Vto (MPH)	29.40	32.20	33.50	34.40	34.70	35.56
Calculated Vto (ft/s)	43.12	47.23	49.13	50.45	50.89	52.15
Calculated .7Vto (mph)	20.58	22.54	23.45	24.08	24.29	24.89
Calculated .7Vto (ft/s)	30.18	33.06	34.39	35.32	35.63	36.51
Thrust Coefficient at Vto	0.79	0.78	0.76	0.74	0.74	0.73
Thrust at Vto (lb)	7.03	6.94	6.76	6.59	6.59	6.50
Average Acceleration ft/s^2	8.99	7.13	6.30	5.71	5.58	5.22
Calculated takeoff distance Sg	71.21	111.53	138.70	162.75	170.08	192.41

In values in Table 9 above, were used mainly to arrive at the theoretical take off distances for the seven flight tests that were performed and documented. The actual observed results are found in the next section.

4.2 Actual Performance Results

According the SAE Aero Design Rules, a video had to be posted on YouTube by the 22nd of September in order to qualify for an additional 15 points in the competition. As stated earlier, although our team was not able to register for the competition, it decided to stick to all the rules and schedule requirements. As such, the aircraft was completed and flying ahead of schedule. The first flight took place on the 27th of July and the video documenting said event was also posted on YouTube as required a few days later. Please see: http://www.youtube.com/watch?v=fYGNyZ5JZ6g. The aircraft handled beautifully during its first flight. It didn't exhibit any negative aerodynamic behaviors as explained by our pilot after the flight.

After the initial flight trials, the team decided to install the wing struts due to the added stresses. As the loads were increased, the landing distances were increasing, and the team decided to experiment with softer tires to reduce the landing rolling distances. However, it was then realized that the softer tires were adding to our take off distances, so it was decided to go back to the original light and hard tires.

After going back to the hard tires, the team experimented by installing a brake system. However, during testing, the brake system was found to be unreliable. It failed during a test in which the aircraft was carrying an 18.5 pound payload allowing the aircraft to roll past the end of the runway. The entire brake system was then removed.

The last testing occurred on the 16th of November. This time the pilot felt comfortable enough with the airplane to fly it at slower airspeeds and at the accompanying higher angles of attack. In doing so, the aircraft landings took place at slower speeds and the aircraft no longer rolled past the end of the runway. After noting this, the team decided to attempt a flight test with a payload of 20.1 pounds, and the results were completely successful. Below is a summary of the flight tests and the results:

TABLE 10: Summary of Test Flights

Date	Type of Test	Payload [lb]	Metal Plates	Results
27-Jul	First Flight	0	0	Successful first flight.
2-Aug	Struts test	7.6	Payload Carrier Only	Successful flight. 2nd flight cancelled after the vertical tail was accidentally damaged by crew on ground.
23-Aug	Flight test	9.8	1	Successful flight
23-Aug	Flight test	12	2	Aircraft rolled past end of runway on landing. Softer tires to be tested next time.
30-Aug	Softer tires	12	2	Successful flight
30-Aug	Softer tires	13.5	2 ½	Successful flight
30-Aug	Hard tires plus struts added	14.2	3	Aircraft rolled beyond the end of runway on landing. Brakes to be tried next time.
9-Sep	Brake test	15.7	3 ½	Successful flight brakes worked.
9-Sep	Brake test	18.5	5	Brakes failure. Aircraft rolled beyond the end of the runway.
16 Nov	Flight Test	20.1	5 ½	Completely successful takeoff and landing.

The team was only able to do one take off from a restrained starting position on the last testing day because the field was very congested with other RC aircraft. We had actually just gone to a 21 pound payload (6 plates), and had the aircraft fueled up when the field manager refused to allow one of us back on the runway to restrain the aircraft while the engine reached full throttle.

Below is a picture of the aircraft taking off before the two hundred feet mark as required while lifting the 20.1 pound payload:

FIGURE 38: Prototype Taking off Within 200 Feet Mark

4.3 Discussion of Results

The team was able to demonstrate that the aircraft design was quite aero dynamically stable and capable of lifting significant payloads. The actual observed results came very close to the predicted ones.

More testing could have been done, but the team was quite busy with other school obligations and no testing was conducted between the 9th of September and the 16th of November. The testing was very valuable because it allowed the team to gain knowledge of what worked, and just as important, what didn't work.

One major lesson is that the aircraft must be kept as light as possible. The team was extremely conservative for most of the testing even leaving on double sets of locking collars for the wheels to reduce the risk of one coming off. A light aircraft will accelerate quicker with a bigger payload. Said acceleration proved to be the biggest factor in being able to take off within the required distance. Even if the aircraft could carry more payload, if it cannot lift off within the required distance, it is not acceptable.

Another factor that greatly affected our performance was the lack of a head wind during our testing. We were getting maybe a 5 MPH breeze over the airfield which was somewhat helpful. However, a higher wind speed would have reduced our take off distance by a considerable amount and thus increasing the payload amount.

The team was very fortunate to have an excellent pilot. As his confidence with the aircraft increased he began to fly the aircraft at slower airspeeds and higher angles of attacks which greatly reduced the lading rolling distances.

5. Project Management

5.1 Overview

In order for this project to succeed, it is essential that major milestones and requirements be identified and accomplished in a timely manner. The major aspects of this project involve the design, manufacture and flight demonstration of an unmanned aerial vehicle (UAV). Some of the milestones and requirements include the preparation and submittal of a flight video as well as a project report to the SAE Brazil Aero Design Competition Committee.

5.2 Breakdown of Project Requirements

The project was broken down into smaller parts such as the research of airfoil shapes, the engine/propeller combination selection, and cargo bay alternatives. Additionally, as classroom tasks became necessary, further taskings were necessary to accomplish requirements such as presentation slides, reports and our team poster.

In addition to the time required to dedicate to research and perform design work, it is also necessary to timely plan for and prepare the required presentations and reports. The amount of time necessary for the latter has proven to be a substantial time investment into this project.

Another task that we had to perform was registering for the competition. This proved to be an extremely difficult process. First, the team had to wait until the date that the registrations were opened on the website to do so. However, it wasn't until then that the information required to register for the event was known. Many personal details were necessary including obtaining passport numbers for each person of the team including our academic advisor. It was also necessary for each member to join SAE International and obtain an ID number. Many emails were exchanged (in Portuguese) trying to clarify all the questions and requirements. The open registration period ended quite abruptly before we were able to gather all the required information. As a result, the team is now on a waiting list for the phase 2 of the registration process.

5.3 Breakdown of Project Task Responsibilities

TABLE 11: Task Assignments

Required Tasks	Designated Member
Reading of the Rules	All
Initial A/C sizing	Nestor
Motor and Prop Selection	Arjav
Airfoil Design Selection	Andres
Airfoil Design Optimization (CFD)	Andres
Cargo Bay Design	Nestor
Cargo Bay Load Stress Simulations	Arjav and Nestor
Empennage Design	Nestor
Fuselage Design	Nestor
Propose Design Concepts	All
Select Design Consept	All
Optimize Design Concept	Andres/Arjav
Cost Analysis	Arjav
Pilot Search	All
Manufacturing Materials Research	Andres
Manufacture Wings	All
Manufacture Fuselage	All
Manufacture Empenage	All
Prepare Reports	All
Team Poster	Arjav
Register for Competition	Nestor
Fuel Tank Selection	Nestor/Arjav
Fuel Tank Integration	Nestor/Arjav
Weight and Balance	Nestor
Thrust Validation Test	All
Drag Validation Test	All
Flight Testing	All
Post Flight Adjustments	All
Flight Practicing	All
Flight Video	All
SAE Report	All
Wing Load Computations	Nestor
Landing Gear Design and simulations	Andres
Flight Control Areas Calculations	Nestor
Flight Control Rigging	Nestor
Selection of Servors	Nestor
Selectlon of Internal Electrical	Arjav
Selection of Radio	Arjav

5.4 Timeline

TABLE 12: Proposed Timeline

Task	2014											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Research												
Literature Survey												
Competition Registration												
Design												
Calculation and Analysis												
Control and Stability												
Computational Fluid Dynamics												
Prototype Construction												
Pilot Selection												
Wind Tunnerl Testing												
Revise												
Report and Drawings to SAE												
Practice Flights												
Design Change Report to SAE												
Flight Video												
Pilot Change Form if Required												
Competition												
Senior Design Report												
Senior Design Presentation												

5.5 Cost Analysis

Every project has some sorts of restrictions, for us it was the rules given to us by SAE. The most important restriction on us as future engineers and current engineering students is the cost of the project. As engineers we did our research as to what type of materials to use, also brainstormed heavily in what ways to manufacture efficiently while keeping the cost in mind. Most of the plane is manufactured out of wood, mainly balsa with some ply and light ply used as reinforcement. Our original cost estimates were as follows:

TABLE 13: Estimated Prototype Costs

Prototype Costs	Amount ($)
Engine	170
Propellers	20
Radio Controller	300
Servos and Electronics	200
Fuel Tank	20
Payload	50
Batteries	100
Manufacturing Materials	150
Landing Gear	30
Flight Control Rigging	25
Operating and Misc	100
Estimated Airplane Costs=	1,165

TABLE 14: Estimated Competition Costs

Competition Costs	Amount ($)
Registration	600
Travel Expenses	1000 per person
Total event cost per person	1,200

The actual costs were very close to our original estimates. We first got all the wood cut, and bought most of the materials, and then we started buying all other components like engine, fuel tank, fuel, batteries and many more. The total cost of the plane came out to $1122.58, which was split evenly between the 3 of us. The breakdown of the costs can be found below:

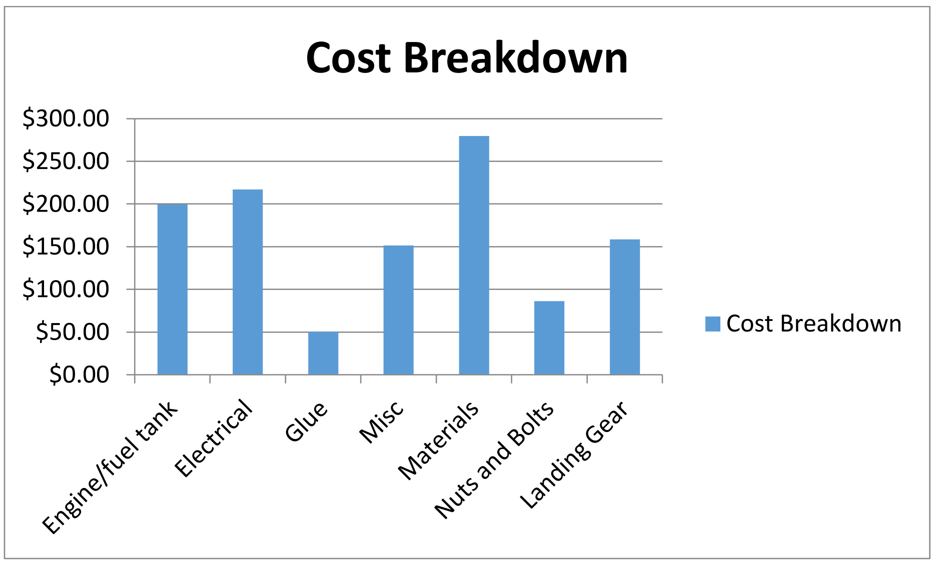

FIGURE 39: Actual Cost Breakdown Amounts

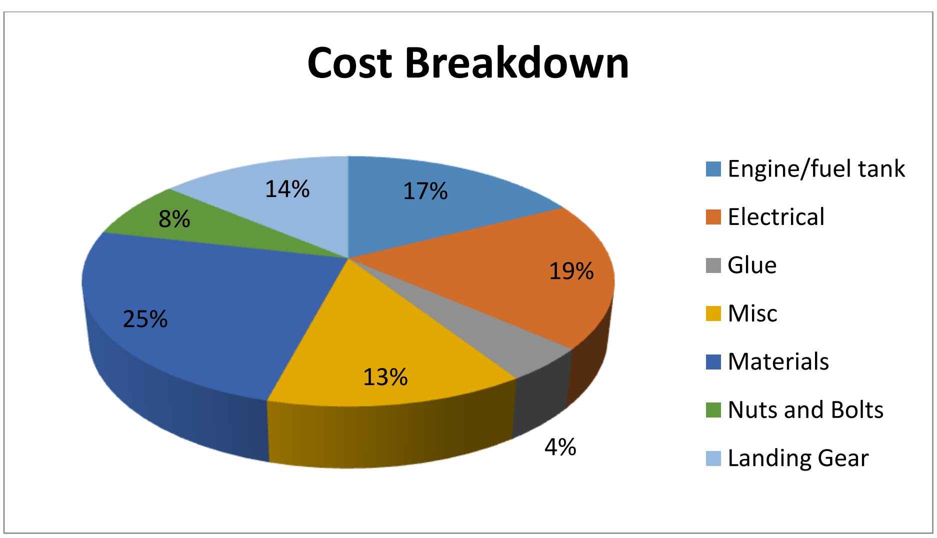

FIGURE 40: Actual Cost Breakdown Percentages

5.6 Building of Prototype

The manufacturing and assembling of the prototype began on the 6th of June by having our wood materials get laser cut. Below is a picture taken when the laser cutting process began:

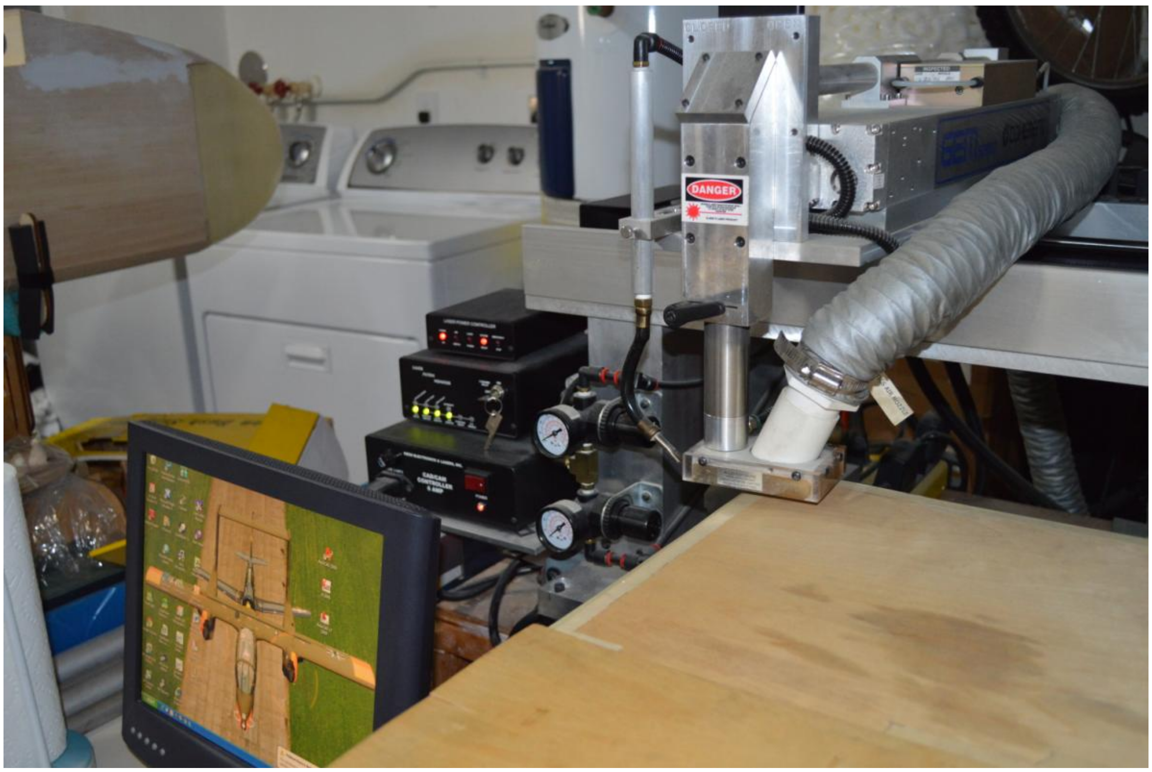

FIGURE 41: Laser Cutting of Wood Parts

Laser cutting of the parts produces quicker, more consistent and accurate results than hand cutting the materials. After having all the necessary wood parts, the wing and fuselage were constructed.

The process for constructing the wings and fuselage was difficult and time consuming. It begins by first printing a 1:1 scale drawing of the assembly, taping it to a flat surface and then covering it with clear plastic taped on top of it. The parts are then placed exactly as they are shown on the drawings and bonded together using

Cyanoacrylate (CA), also known as “Super Glue” adhesive. A spray chemical known as CA “Kicker” was also used to speed up the drying time for the CA.

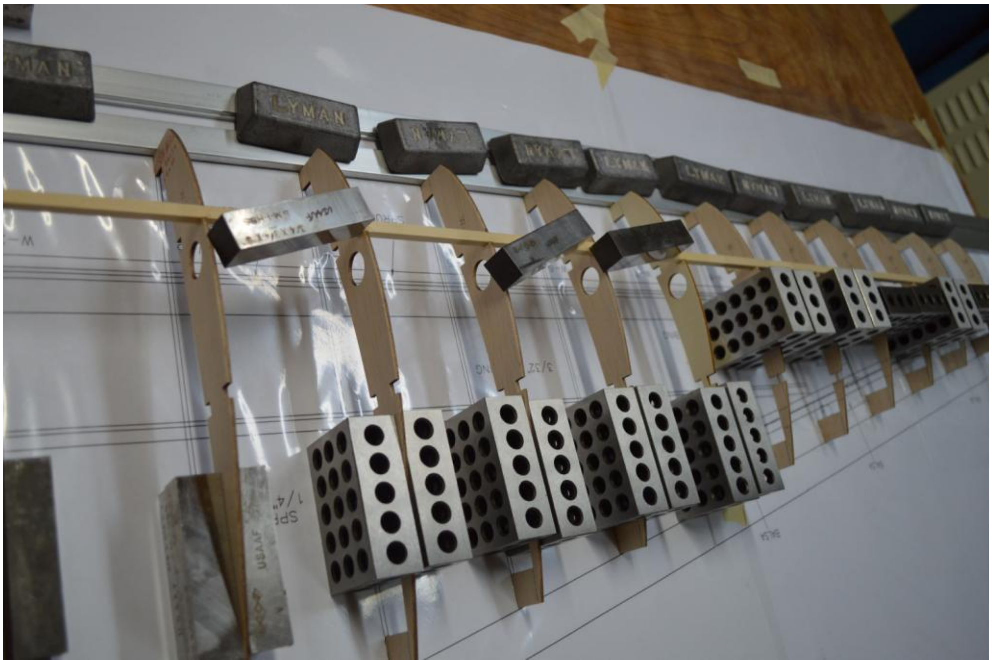

FIGURE 42: First Wing Being Built

FIGURE 43: Wing Planking Being Installed

As shown in figures 42 and 43, the assembling of the wing was not an easy process, and it required the use of many steel blocks to make sure that the ribs were maintained perpendicular to the table and to provide support.

FIGURE 44: Fuselage and Wing Constructed

FIGURE 45: Vertical and Horizontal Tails Added to Fuselage

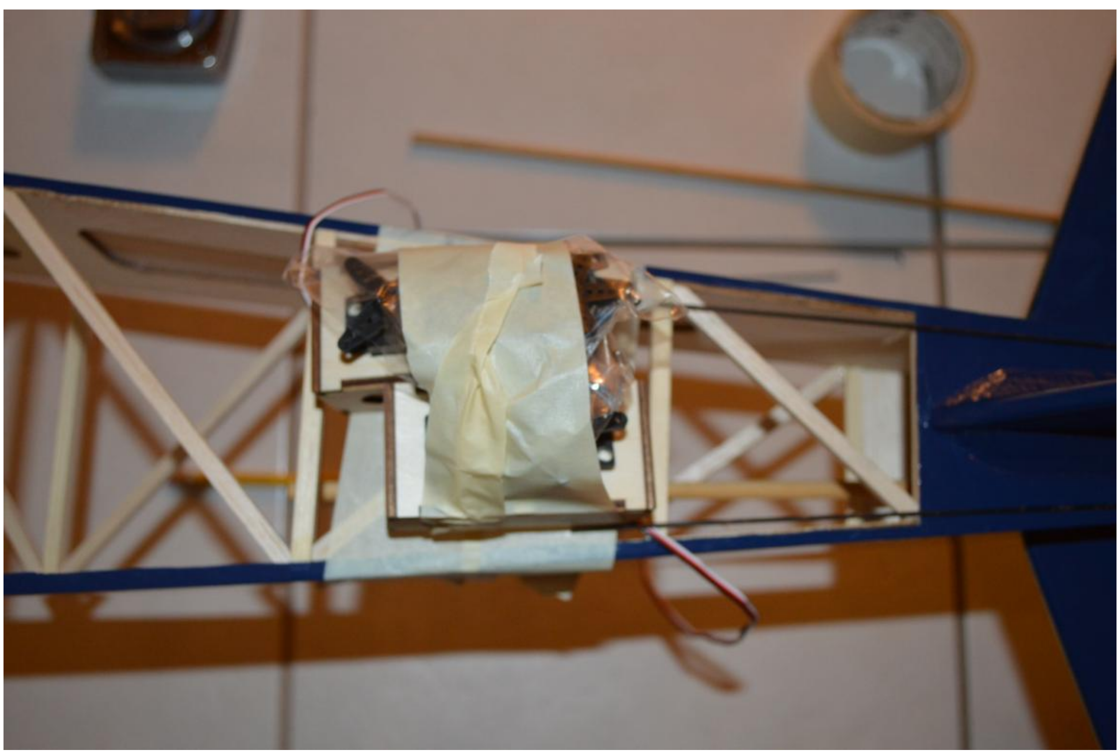

FIGURE 46: Components Taped on for Balancing Tests

Special considerations were taken to make sure that the CG of the aircraft fell within the initial design goal. As such numerous experiments to validate the actual CG were made during the assembly process. During this time, all the required components such as the aircraft battery, control linkages and servos were temporarily taped on to validate the best possible location for them prior to permanently installing them. This method allowed us to maintain a CG exactly where it was needed to be.

The building of the prototype took place during the summer, and it required a team effort to succeed at it. It should be mentioned that our pilot also dedicated his time to help us in building our prototype. Below is table breaking down the estimated hours spent on the project:

TABLE 15: Hours Spent on Project

Individual hours	Hours spent/week	Hours spent so far
Andres	20	720
Arjav	20	720
Nestor	20	720
Total hours	60	2160

6. Global Components of Project

Globalization is a very important aspect for all engineers. Engineers have to consider units and various languages to make their product global. Every industry is trying to tap into new markets to increase revenue. As an engineer, one has to design the product according to requirements while keeping in mind the potential global aspects.

The SAE Aero design competition is one of the most globalized competitions in the world in Aero Design. The most global aspect of this project is that the competition is held in Brazil. It was very important for the team to be able to communicate with the SAE international members in Brazil. Since the country's official language is Portuguese, it put a huge challenge in front of the team to effectively communicate with them. Four countries from across the globe were able to register for the competition. The rest were Brazilian teams, and it shows how difficult it is to get into the competition to begin with. There was a very long waiting list which the FIU team was listed 17^{th} on.

The next SAE competition is in March of 2015 in Lakeland Florida, and it has eight different countries registered to attend. The Aerospace Engineering Club representing Florida International University is registered to attend.

Brazil is a country that follows the metric system, and therefore the rules for the competition were published in metric units so the team had to convert the units to British units and design the airplane accordingly. If the team had gone to competition, it would have had to write a report and include all dimensions in metric units and present them accordingly. Since the design is a conventional design a good pilot would be able to fly the plane like a regular fixed wing aircraft, therefore no need for a manual since one would know how to fly a plane before trying to fly a heavy lifter airplane.

7. Survey of Related Standards

Introduction

The focus of this project was to design, build and fly a remote control airplane capable of competing in the SAE Brasil Aero Design competition. As such, the immediate and most relevant standards that had to be surveyed were the competition rules. These rules govern many topics from team composition to aircraft size limitations. These rules are written in Portuguese, and the team had to translate them in order to fully understand all the requirements.

Standards Used in the Project

The standards that were applied to this project were limited to the following:

- SAE Aero Design Rules
- American Society of Mechanical Engineers
- American National Standards Institute
- Institute of Electrical and Electronics Engineers
- Academy of Model Aeronautics
- Federal Aviation Administration

The Society of Automotive Engineers is the entity in charge of regulating the SAE Aero Design competition. They are in charge of promoting and writing the rules and regulations for the competition as well as the sanctioning of the competition's scores. The SAE Aero Design rules regulates the design parameters of all competing aircrafts in terms of size limits, allowed materials, fuel composition, safety and logistics. The team had to comply with these regulations and it made sure the aircraft fell within the allowed design, test and manufacture parameters. More on the rules are contained in the Appendix.

Standards were also researched at the component level for our project including materials, electronics, fuel tank, engine, wood, propeller, landing gear, wheels and fasteners. All these items were commercially available in hobby and/or hardware stores. Unfortunately, it was noted that no reference to any standard was documented on any of the packaging of these components. There was also no mention of any standard being applied when researching by going to the websites for the different sources. However, it was noted that at least the hardware and the rechargeable batteries did have to comply with some standards as explained in the following paragraphs.

The American Society of Mechanical Engineers (ASME) in conjunction with the American Standards Institute (ANSI) provides guidance and requirements to many industrial items including tools and fasteners. In order to construct the airplane for this project, the team had to purchase and use a variety of commercially available fasteners from a number of different sources. Although the team was unable to find any specific reference to any specific standards on any of the hardware that was used, it would be very unlikely that they were not made in accordance to the required standards.

The Institute of Electrical and Electronics Engineers (IEEE) sets standards for rechargeable batteries. Our airplane's main battery is a rechargeable battery which would have to comply with the standards for the IEEE.

The Academy of Model Aeronautics (AMA) is the official regulatory entity for remote control (RC) aircraft in the United States. It is dedicated to the promotion of RC aviation as a sport as well as a recreation activity. The AMA also sanctions RC model airplane competitions, maintains RC airplane standards for flying sites and runways, and certifies flying records. In order for the team to be able to compete and test the aircraft, it was necessary for our pilot to have a valid AMA license. This license certifies that our pilot is capable to fly RC model airplanes and makes sure he follows all protocol and safety rules when flying the aircraft. This license also provides insurance in case of an accident.

The main regulatory body for operation of model aviation as well as all other forms of real sized commercial and military aviation is the Federal Aviation Administration (FAA). For the purpose of this project, the FAA Advisory Circular 91-57 covers the normative for the use of recreational model aircraft. It mainly restricts the flight of model aircrafts to an altitude of 400 ft and in zones where airport areas are not in sight of the pilot. The document is also clear on the fact that the FAA will take enforcement actions against anyone that violate their regulations in an effort to protect users of the airspace as well as property on the ground. The frequency range allowed for remote control aircraft radios is also governed by the FAA.

8. Conclusions

The team got off to a difficult start due to the fact it spent a bit more than a month conducting research and design work using the only available rules at that time which were the 2014 SAE East Aero Design Competition rules. Upon the publishing of the 2014 Brazil Aero Design rules, it was realized that our design would be substantially different. For example, it went from electric propulsion to internal combustion, the geometric requirements were substantially changed, and the required minimum cargo bay volume was not even required in the prior rules. All of this resulted in a small shift of our timeline.

One area that the team had dedicated countess hours on was on performing simulations and analysis on the custom FIU airfoil, the Reddy-LR-007. The team could have chosen to use an already researched and proven airfoil at the time, but felt that the experienced gained by conducting our own research would be very valuable. It was also deemed that we might end up with a better performing airfoil. Eventually, the team picked an existing airfoil design as previously discussed in the report.

Another obstacle that the team faced was the fact that it was not able to secure a slot in the competition in Brazil. However, it was decided to continue its research, design, manufacture and fly the prototype while following all the rules.

Lastly, the team was able to find an outstanding RC airplane pilot from within the FIU student population. His name is Kishan Kapoe, and he is a sophomore. He participated while we were still in the design stages by attending our team meetings where he offered his expertise and advice from a pilot's perspective.

SAE Brazil Aero Design released the results of the competition just before printing this report. There are some very interesting observations that should be noted here. The teams that won 1st and 2nd place of the competition are also the same teams that won 1st and 5th place in the SAE East Aero Design Competition held in Georgia, United States of America in April of 2014. Obviously, they are excellent competitors with proven track records.

Another interesting observation, and a previously stated goal of this project was to compare how theoretically our team might have performed at the event had the opportunity presented itself. Obviously, there is no objective way to compare things like our reports or presentations, but we wanted to compare the payload carrying results. As noted in table 16 below, it is quite possible that our team might have been able to achieve a spot in the top 10 teams based on reported payload carrying results.

PanthAir Cargo demonstrated a successful flight carrying a payload of 20.1 pounds which converts to 9.12 kg. This amount is greater than the 10th place team which carried 8.415 and very close to matching the 4th place team which lifted 9.200 kg. A total of 95 teams competed at the event. The results for the payload carrying capacities for the top twenty five teams are shown in the Table 16 below:

TABLE 16: Summary of Official Results [21]

Pos	Nº Equipe	Nome Equipe	Escola	UF	Carga Paga Total (kg)
1	002	Urubus	Universidade Estadual de Campinas	SP	10.310
2	001	UIRÁ	Universidade Federal de Itajubá	MG	12.295
3	009	EESC-USP Alpha	Escola de Engenharia de São Carlos	SP	11.125
4	024	FEI Regular	Centro Universitário da FEI	SP	9.200
5	013	CEFAST AERODESIGN	CEFET - MG	MG	10.830
6	015	Tucano Aerodesign	Universidade Federal de Uberlandia	MG	10.720
7	005	Keep Flying	Escola Politécnica da Universidade de	SP	9.255
8	012	Aerofeg	Universidade Estadual Paulista - Gua	SP	10.590
9	004	Uai, sô! Fly!!! Kids	Universidade Federal de Minas Gerais	MG	9.660
10	008	F-Carranca	UNIVASF	PE	8.415
11	010	EESC-USP Bravo	Escola de Engenharia de São Carlos	SP	9.715
12	003	Uai, sô! Fly!!!	Universidade Federal de Minas Gerais	MG	7.000
13	006	Aero Vitória Espirito Santo	Universidade Federal do Espirito Sant	ES	9.140
14	022	Triângulo Aèreo	Universidade Federal do Triângulo Mi	MG	9.450
15	031	Acauã	Universidade Federal de Viçosa - cam	MG	8.070
16	033	Harpia	Universidade Federal do ABC	SP	7.470
17	014	ICARO	UNIVERSIDADE NOVE DE JULHO	SP	7.960
18	025	kamikase aerodesing	unisc	RS	4.865
19	026	BlackBird Aerodesign	Universidade Federal Fluminense	RJ	7.420
20	017	UFSCar Dragão Branco	Universidade Federal de São Carlos	SP	7.135
21	038	MINERVA AERODESIGN	UNIVERSIDADE FEDERAL DO RIO	RJ	4.340
22	043	AerodesignVenezuela 1	UNEFA	Venez	7.840
23	040	Aero Design SAE USB	Universidad Simón Bolívar	Venez	5.950
24	019	Albatroz AeroDesign	Universidade do Estado de Santa Cat	SC	4.425
25	037	FEB REGULAR	Universidade Estadual Paulista Júlio	SP	5.115

In conclusion, it is fair to say that although the team was not able to compete in Brazil, the team members feel very good about what we were able to achieve. Considering the fact that that this was a small group of students with no sponsorships, no previous knowledge or experience with this event going against the best teams in the world with members exceeding 20 per team, having big sponsors, extra airplanes and parts, dedicated research, etc, it is hard to arrive any other conclusion other than this project was an absolute success for PanthAir Cargo and FIU.

PanthAir Cargo had one other goal to achieve which although was not part of this project, it is still relevant and should be mentioned. The team decided to begin a new club at Florida International University that among other things would help future teams better organize and prepare for future SAE Aero Design competitions. The name of the club is the Aerospace Engineering Club. The club is currently very actively working on the design and manufacture of an aircraft that will compete in the next SAE Aero Design competition held in Lakeland, Florida in March of 2015. The club hopes that this partnership with Florida International University will lead to successful performances at future events representing our outstanding university.

FIGURE 47: Team PanthAir Cargo After a Successful Last Flight

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21. SAE Brasil Aero Design 2014

Appendices

Appendix A: SAE Brasil Competition Rules

The 16th Annual SAE Brasil Aero Design 2014 rules include a total of 104 pages written in Portuguese. The rules may be downloaded from their website: http://www.saebrasil.org.br/eventos/programas_estudantis/aero2014/Regras.aspx

The first few pages of the rules including the Table of Contents are contained in the following pages in order to provide a reference to the reader of what was included in the event rules.

SAE BRASIL
Sociedade de Engenheiros da Mobilidade

16ª Competição SAE BRASIL AeroDesign 2014

Classes Regular, *Advanced* e Micro
Regulamento da Competição

Elaborado pela Comissão Técnica da Competição

Revisão_01

20 de Fevereiro de 2014

105 páginas

DICAS PARA LEITURA DESTE DOCUMENTO

Observar sempre a quais classes da competição cada capítulo ou seção é aplicável.

PARTE A

Seção inicial (Capítulo 1 ao 4): É aplicável a todas as classes da competição. Nela são divulgadas:

- Informações de aspecto gerais da competição
- Objetivos da competição
- Regras gerais comportamentais

PARTE B

Introdução: Aspectos gerais da Competição SAE AeroDesign no Brasil.

Capitulo 6: Requisitos iniciais. Válidos para a Classe **Regular**, ***Advanced*** e **Micro**.

Capitulo 7: Requisitos de Projeto válidos SOMENTE para a Classe **Regular**.

Capitulo 8: Requisitos de Projeto válidos SOMENTE para a Classe ***Advanced***.

Capitulo 9: Requisitos de Projeto válidos SOMENTE para a Classe **Micro**.

Capitulo 10: Requisitos de Missão. Válidos para as Classes **Regular**, ***Advanced*** e **Micro**.

Capitulo 11: Regras Gerais para Relatórios e Apresentação (Competição de Projeto). Válidas para as Classes **Regular**, ***Advanced*** e **Micro**.

Apêndices: Classes **Regular**, ***Advanced*** e **Micro**, conforme o caso.

SAE BRASIL
Sociedade de Engenheiros da Mobilidade

ÍNDICE

Sociedade de Engenheiros da Mobilidade

SAE BRASIL
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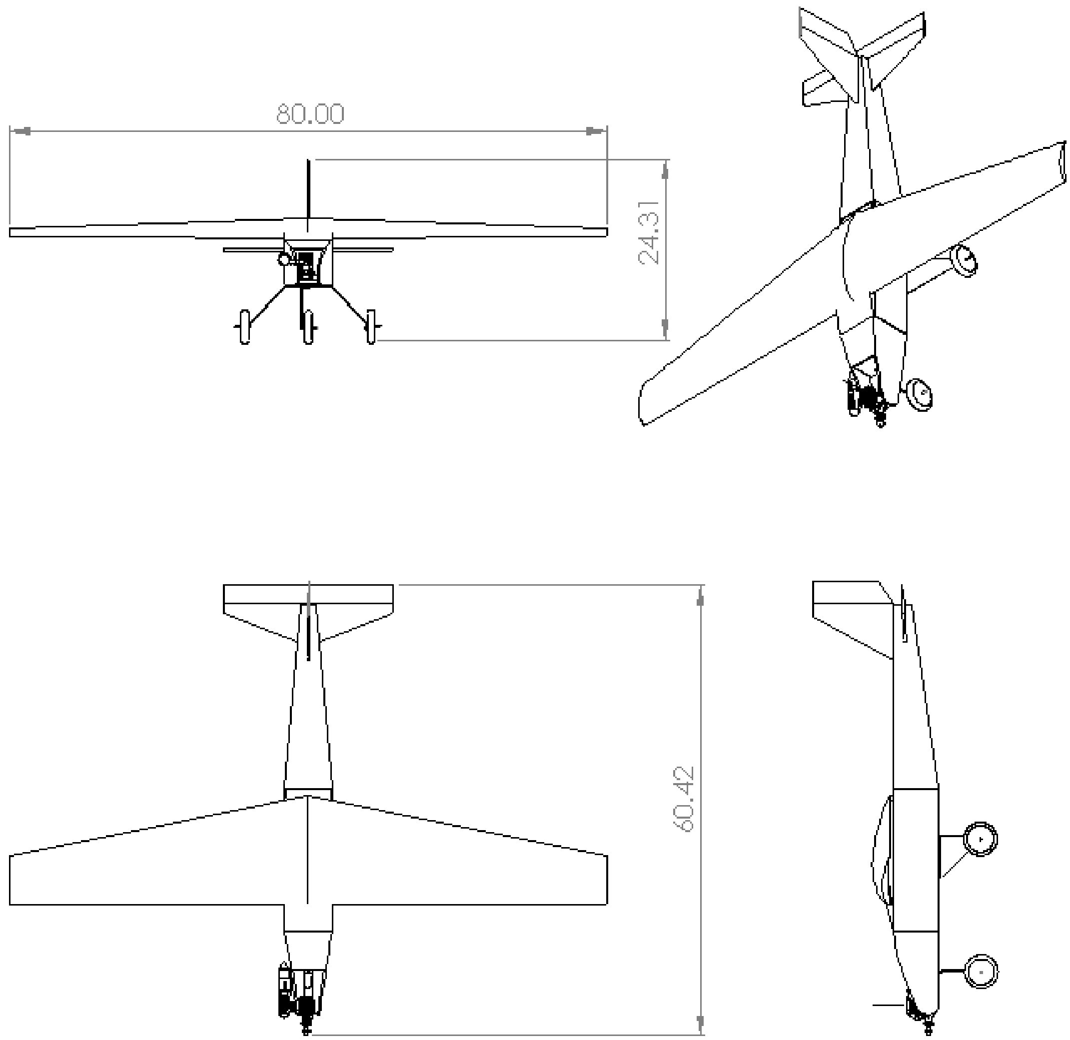
Appendix B: Prototype Initial Sizing Sample Calculations

	inches	meters
Calculated span bw	80.90273	2.054929
Cwingroot	14.68289	0.372945
Cwingtip	6.607301	0.167825
Wing Desired taper ratio λ	0.45	0.45
Max Wing Area Sw	861.2174	0.555623
Average chord, c w average	10.6451	0.270385
Calculated aerodynamic MAC	11.15562	0.283353
Desired Wing Aspect Ratio AR	7.6	7.6
Max Hor Tail Area Sht	129.1826	0.083343
Horiz Tail Desired taper ratio λ	0.45	0.45
Calculated Hor Tail Chord root	7.838519	0.199098
HT Chord tip	3.527334	0.089594
Calculated ht MAC	5.955473	0.151269
.25 ht MAC	1.488868	0.037817
Calculated span bht	22.73171	0.550962
.25 wing MAC	2.788906	0.070838
average chord c ht average	5.682926	0.144346
Horizontal Tail Volume Coeff.	0.5	0.5
Desired Horizontal Tail Aspect Ratio	4	4
Horizontal Tail Arm Lht	35.48365	0.901285
Desired Vertical Tail Volume Coeff.	0.04	0.04
Vertical Tail Surface Area Svt	83.9687	0.041672
Desired Vertical Tail Aspect Ratio	1.5	1.5
Desired Vertical Tail Desired taper ratio λ	0.45	0.45
Vertical Tail Arm Lv	33.19086	0.843048
Vertical Tail span bv	11.22288	0.285061

Appendix C: Prototype Reference Drawing



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