Concept Generation and Selection

EML 4551C – Senior Design – Fall 2011 Deliverable

Team # 10

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Project Introduction

The purpose of our project involves the design and construction of a remote-controlled aircraft which fulfills the 2011-2012 regulations and mission requirements for submission to the SAE Aero Design East competition to be held in Marietta, Georgia. In order to be considered successful, the aircraft must lift as much weight as possible while observing requirements governed by the SAE Aero Design East committee. Furthermore, the aircraft must accomplish the specified mission while embracing the integrity of the design as defined in the technical report.

With regards to competition guidelines, the design project is to be structured around three critical phases: a technical report, a technical presentation/inspection, and the physical flight competition. The technical report functions as a means by which the design team can convey how their aircraft is most suited to complete the mission requirements. It details the methods, procedures and calculations (where applicable) used to arrive at the final product. The design report will be an integral part of the total competition score encompassing 50 points subdivided in the following manner: Report – 40 points, Plans – 5 points, and Payload Prediction Graph – 5 points. Prior to the technical presentation, a timed demonstration of the payload loading/unloading of the aircraft will be performed in order to confirm the ability to complete said tasks in one minute respectively. The technical presentation is to be a ten minute oration of the content presented within the technical report delivered in the same manner a "pitch" to an industry customer would occur. The design team will focus on providing detailed explanations as to why certain design configurations were chosen and present the results of any pertinent analysis/testing performed during the conception of the design choice. The oral presentation is to be scored out of a maximum of 50 points.

The overall competition score is to be calculated as the sum of these individual components,

$$\boldsymbol{Overall\ Score = Design\ Report\ Score + Oral\ Presentation\ Score + Flight\ Score}$$

Product Specifications

Customer Needs

- Aircraft has a maximum combined length, width, and height of **225 inches.**
- Aircraft weighs no more than **55 lbs.** including payload and fuel
- Team number visible on both sides of the vertical stabilizer and wing using **4 inch** decals
- Payload is not to be integrated as to affect the structural integrity of the airframe
- Payload is to be secured to the cargo bay in a manner as to not shift during flight
- Use of a 2.4 GHz radio is required for aircraft operation
- Battery pack to have a capacity of no less than 1000 mAh
- Only common grade, 10% nitro methane fuel permitted
- Fuel tank is accessible and pressurized using only stock fittings from the engine muffler
- Powered by a single, unmodified O.S 61FX engine with stock E-4010 muffler
- 1:1 propeller to engine RPM is required thus any gearbox, drives, or shafts must allow this ratio to be maintained

The general product specifications call for a lightweight, fixed-wing remote-controlled aircraft possessing heavy payload lifting capacity. The aircraft must be able to takeoff in less than 200 feet, ascend, turn completing a 360° lap and finally land in a designated landing zone of 400 feet while carrying its maximum payload. Analyzing and converting the customer needs to product specifications, we have determined the following are desired characteristics for our aircraft: high L/D ratio, high structural efficiency factor, maneuverability, and a high aspect ratio. It is important to attempt to incorporate all of these factors while maintaining a lightweight wing construction as surely this is of utmost importance in our design.

Concept 1: Conventional Design

The conventional aircraft design layout is exactly what its name insists, conventional. This has been the chosen design for flight since the early 1900's. The design has stood the test of time for several key reasons. One reason is because of its durability. The central fuselage allows for a sturdy back bone for the aircraft to be based on. It also allows adequate room for cargo, pilots, and passengers without disturbing the overall air foil dramatically. Possibly it's most important trait is its stability. In most configurations the conventional style aircraft design is extremely stable allowing ease of flight and control. Within the conventional design there are several possible tail layouts that have their own flight characteristics. Several tail layouts are pictured below:

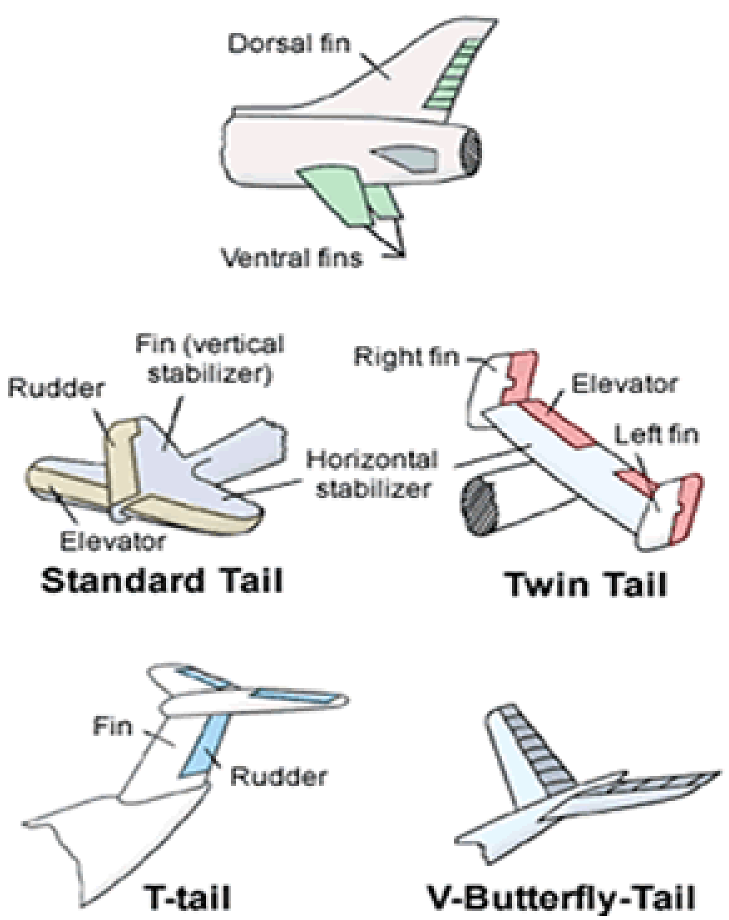
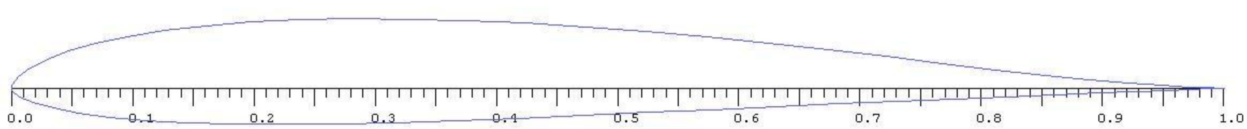


Figure 1: Several types of tail configurations

Concept 2: “Flying Wing” Design

A clean flying wing is theoretically the most aerodynamically efficient design configuration for a fixed wing aircraft. It also offers high structural efficiency for a given wing depth, leading to light weight and high fuel efficiency. Because it lacks conventional stabilizing surfaces or the associated control surfaces, in its purest form the flying wing suffers from the inherent disadvantages of being unstable and difficult to control. These compromises are difficult to reconcile, and efforts to do so can reduce or even negate the expected advantages of the flying wing design, such as reductions in weight and drag. This concept will required a special airfoil that makes the aircraft stable without a tail.



Airfoil example (moment coefficient tends to 0)

Concept 3: Minimalist Design

The minimalist design is intended to minimize the amount of material used to construct the aircraft while maintaining the integrity of a structurally sound, maneuverable airplane. Constructing an aircraft in this manner facilitates the possibility for creating a lightweight fuselage and airframe. These factors are important because minimizing the weight of the airframe gives one the ability to allocate more material to constructing a larger wing. A larger wing therefore provides more lift surface area for an optimized lift force. Many minimalist designs incorporate a "boom pole" style airframe rear which attaches to the aircraft's aft. Not only does this reduce the total weight of the aircraft but it also minimizes the drag induced on the aircraft by the free flow air stream while in flight. It is plausible to use carbon composite tubing in combination with either a conventional tail or H-tail, in order to compensate for the possible loss in flight stability, to ensure the lightest weight while maintaining control of the aircraft. Some issues that may arise with this design option are the doubt in the aircraft's ability to attain high wing load configurations in the presence of heavy wind gusts. Lacking uniformly distributed mass inhibits this capability thus the strength of the overall aircraft becomes of concern when weighed against variables that may not be in our control such as weather conditions.

Figure 2: UFPR aircraft implementing two carbon fiber tubes connecting the aft to the airframe

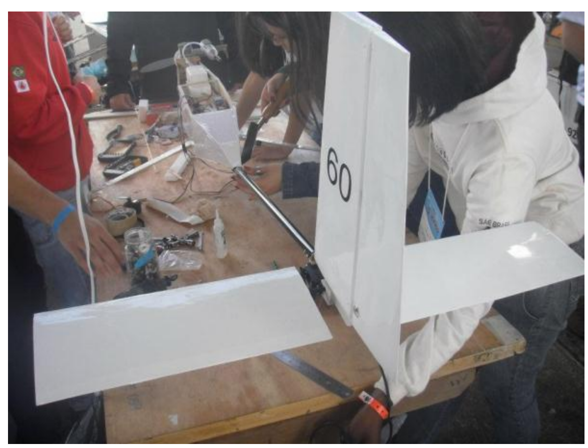


Figure 1: Lightweight, minimalist design featured at SAE Brazil Aerodesign competition

Concept 4: Canard Wing Design

Canard wing design is an application to aircraft that is not widely used. The basic idea behind the design is a two-wing application where the front wing is smaller than the back wing. On some designs, the front wing is almost as large as the rear wing. The main reason for this design is to increase lift on the aircraft. While this is accomplished by the unique wing layout, there can be negative effects, such as airflow disruption from the front wing to the back wing. When designing a canard wing system, it is very important to choose the appropriate length for the canard. There exists little room for error in this selection. The smallest change in length can drastically alter the flying performance of the aircraft. Throughout the years, many different types of planes have successfully adapted the canard wing design. From private use to military jets, canard wing design can be found in almost every type of application. Pictured below are some of the more successful designs.

Figure 3: Commercial jet using Canard style wing

Figure 4: Solo aircraft with a Canard-style wing

Concept 5: Bi-Plane Design

A bi-plane is an aircraft with two fixed main wings. The bi-plane dominated aviation history for the first 30 years following the Wright brothers' Wright Flyer design. This wing structure influenced the Wright brothers from a civil engineer and his concepts in bridge building. Early airfoils were thin requiring external bracings, therefore the bi-plane is perfect as its arrangement and truss-like bridge structure provides for more structural efficiency than an externally braced monoplane.

Bi-planes are assumed to lift twice as much as a similar chord monoplane; however this is not the case. The wings actually interfere with the aerodynamics of one another, reducing lift and increasing drag. A simple alteration is seen in the case of tandem wing, when the bottom wing is placed at the front of the aircraft and top at the back, giving a advantage of 20% more lift than a single wing but also gives higher tip vortex drag than the equivalent monoplane. Bi-planes typically have a shorter wingspan however, giving greater maneuverability. Now with thicker stronger airfoils, the bi-plane is mainly used for recreation.

As for creating a RC bi-plane for competition, the advantages to the flight score look slim to none as drag is increased and lift is decreased to a standard monoplane, and any advantages to an alteration to the bi-plane (tandem) will be time consuming and difficult to perfect. The large size and structure of the biplane maybe costlier in terms of material costs and build time. Advantages will come in form of lightweight and strong wings wing structure and greater maneuverability.

Figure 6: Biplane aircraft design from Brazil Aerodesign competition

Decision Matrix

Decision Matrix											
Rating: 1 - 10	Concepts										
		Standard Design		"Flying Wing" Design		Minimalist Design		Canard Wing Design		Bi-Plane Design	
Selection Criteria	**Weight**	**Rating**	**Weighed Score**	**Rating**	**Weighed Score**	**Rating**	**Weighed Score**	**Rating**	**Weighed Score**	**Rating**	**Weighed Score**
Potential Lift	20%	7	1.4	9	1.8	8	1.6	8	1.6	7	1.4
Potential Drag	10%	4	0.4	8	0.8	9	0.9	2	0.2	3	0.3
Durability	15%	9	1.35	5	0.75	3	0.45	7	1.05	7	1.05
Cost	10%	5	0.5	5	0.5	8	0.8	3	0.3	4	0.4
Ease of Build	5%	5	0.25	6	0.3	8	0.4	4	0.2	4	0.2
Potential Flight Score	40%	8	3.2	6	2.4	7	2.8	7	2.8	7	2.8
	Total Score	7.1		6.55		6.95		6.15		6.15	
	Rank	1		3		2		4(tied)		4(tied)	

References

http://www.strange-mecha.com/aircraft/Ente/canard.htm
http://www.esosi.org/planes/Canard-1.jpg
http://www.rcgroups.com/forums/attachment.php?attachmentid=3697947