The Wright Stuff

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Configuration Selection and Decision Making

Document

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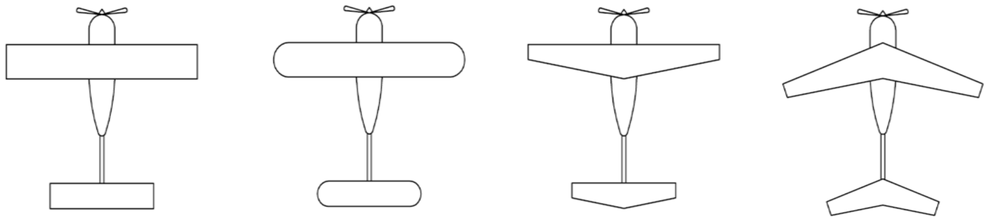
1. Introduction

In this project, the group will design and manufacture a remote-controlled aircraft that can transport twenty-five pounds of payload in the Society of Automotive Engineers (SAE) Aero Design West 2013 competition. To this end, team The Wright Stuff will be implementing the engineering design process in the development of a high quality product. This report details the crucial steps of concept generation and decision-making in this design process.

The technology of high lift aircraft design is already well-understood. Therefore, the team will not seek to “reinvent the wheel” by developing a new design from scratch. Instead, the objective for this team is to optimize the system through a series of selection and configuration design processes. The success of the final product will ultimately be the result of sound analysis and precision manufacturing.

2. Airfoil Planform

The airfoil planform is a fundamental design consideration because it significantly impacts the performance characteristics of the aircraft in areas such as lift, drag, ease of manufacture, weight, and stability. In this category, five designs were considered, as described below. The decision-making process constituted a decision matrix which compared the strengths and weaknesses of each design.



Square Elliptical Tapered Swept and Tapered

Figure 1: Common Planforms

2.1 Square

The square planform is advantageous because it has the largest total area, and therefore can generate the most lift. Also this type of wing is easiest to manufacture because the cross-section is uniform for the whole plane. The downsides inherent in this type of wing are the large weight and considerable induced drag due to vortex generation at the wing tips.

2.2 Elliptical

The major advantage to an elliptical planform is induced drag reduction, accomplished through curved wing tips. The major downside to this approach, however, is that such curved wing tips are very difficult to manufacture.

2.3 Tapered

Tapered wings offer similar high lift and ease of manufacture advantages of the square planform while also reducing the induced drag. Moreover, the tapered wings perform consistently well in all categories.

2.4 Swept

The main advantage to a swept planform is the increased stability that results from a tail-up moment generated as the lift contributions of the wing are spread backwards toward the tail. The disadvantage of this resulting moment is that the wings must be built with more strength to withstand it. This causes an increase in weight and makes the design more difficult to manufacture.

2.5 Swept and Tapered

Swept and tapered wings are the industry standard for high lift aircraft today. The foremost advantages of this approach are stability and induced drag reduction. However, the difficulty of manufacture in this wing type is great, which makes the swept and tapered planform impractical for this project.

Table 1: Airfoil Planform Decision Matrix

Concept	Criteria					Score
	Lift	Drag	Ease of Manufacture	Weight	Stability	
Square	1	4	1	4	3	13
Tapered	3	2	2	2	3	12
Elliptical	5	1	5	2	3	16
Swept	1	4	4	4	1	14
Swept & Tapered	3	2	5	3	1	14

This decision matrix shows the tapered wing planform as the optimal choice, with the square planform a close second option. Further analysis throughout the design process, the group will apply specific calculations in order to make a final decision between these two options.

3. Wing Configuration

The wing configuration and layout is a crucial aspect of the design of the aircraft. It defines the location of the wing relative to the aircrafts fuselage. The key constraints used in finalizing the type of wing configuration include: lift, drag, manufacturability, weight, and maneuverability. The types of wing configurations we have decided upon from many of options comprise of a single high wing, single mid wing and a biplane. Refer to Figure 2 for a representation of these types of configurations.

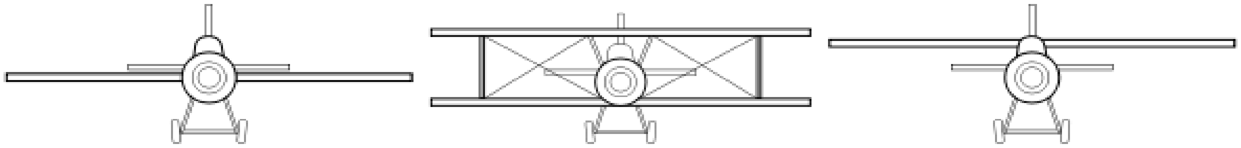

Single Mid
Double
Single High

Figure 2: Wing Configurations

3.1 Double

There are many advantages with the use of a double. First, the double wing consists of two wing sets, highly increasing the lift of the aircraft which plays a crucial part in this design project. Second, because the double wing offers the large amounts of lift and travels at lower velocities, it provides tight maneuverability. However, our design does not require very much maneuverability. Given the advantages of a double wing design, it is found that the disadvantages are greater when compared to the other configurations. The multiple parts of the biplane result in large amounts of drag, weight and cost. Refer to the wing configuration decision matrix in Table 2.

3.2 Single Mid Wing

The single mid wing provides great characteristics in lift, drag, weight and maneuverability; however, the designing and manufacturing of the wing into the fuselage would be very challenging especially when compared to the assembling of the single high wing to the fuselage.

3.3 Single High Wing

This configuration allows the manufacture of a complete wing and easy assembly to the fuselage with a set of brackets. The use of the single high wing will also create a greater space within the fuselage for adding in payload in addition to having more room for maintaining the aircraft.

Table 2: Wing Configuration Decision Matrix

	Criteria					
Concept	Lift	Drag	Ease of Manufacture	Weight	Maneuverability	Score
Single High	5	1	1	1	3	11
Single Mid	4	2	4	3	3	16
Double	1	5	5	5	1	17

This decision matrix shows that the single high wing configuration is the clear choice. As a result, the group plans to pursue this configuration in the final design.

4. Tail Configuration

The tail configuration and layout is a essential to the performance of the aircraft. It defines the location of the elevator on the empennage relative to the location of the main wings location. The fundamental constraints used in finalizing the type of tail configuration include: lift, drag, manufacturability, weight, and stability. The types of tail configurations we have decided upon include a T-tail, no tail and a conventional tail. Refer to Figure 3 for representations of these configurations.

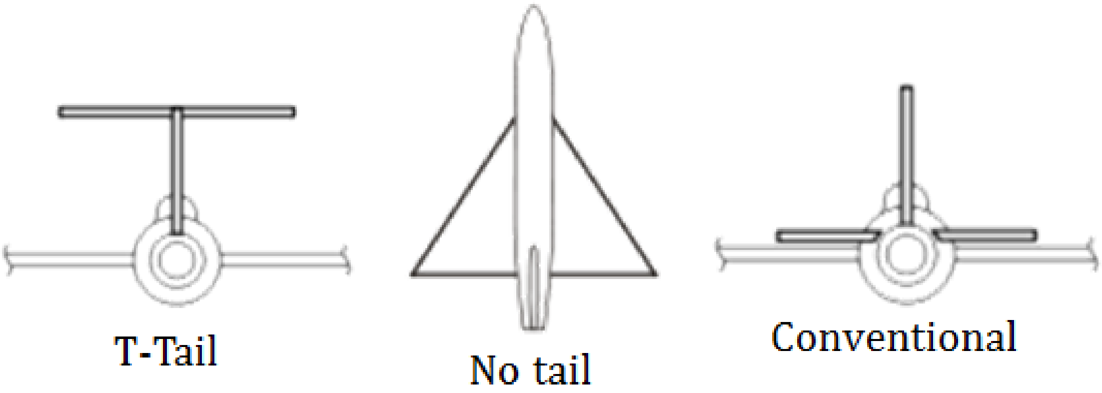


Figure 3: Tail Configurations

4.1 No Tail

A design which does not utilize a tail will suffer in terms of stability, since the tail allows the aircraft to maintain the optimal angle of attack. The omission of a tail, however, could be advantageous because it means the group would have one less component design, enhancing the ease of manufacture.

4.2 T-Tail

The T-Tail offers a larger moment arm than a conventional tail. This increased moment helps the aircraft to be more stable by keeping it level. The drawback to selecting the T-Tail is that it is more difficult to manufacture and it adds weight, as additional structural support is required to locate the airfoils above the central plane of the aircraft.

4.3 Conventional

The conventional tail is advantageous because it increases the lift of the overall aircraft and reinforces its stability through the addition of a moment about the center of gravity. The conventional tail requires some effort to manufacture and adds weight, but not to an extraordinary amount.

Table 3: Tail Configuration Decision Matrix

Concept	Criteria				Score
	Lift	Ease of Manufacture	Weight	Stability	
No Tail	5	1	2	5	13
T-Tail	1	4	4	1	10
Conventional	1	3	3	2	9

The decision matrix compiled for this design consideration shows the conventional tail as the optimal tail configuration, with the T-Tail as a reasonable second choice. The final tail configuration, therefore, is still pending static analysis and testing at this stage.

5. Spar and Rib Design

5.1 Materials

Spar and rib design is a key component to the overall quality of a wing on an aircraft. The spars within the wing represent the main support against various forces on the wing. These forces include upward bending loads generated from lift and drag. Numerous ribs are attached to the main spar to help distribute the loads evenly across the wing. Below are the three material selections identified for manufacturing the spars.

5.1.1 Polymers

Designing the spar and rib with a polymer demands the utilization of rapid prototyping, or 3D printing. 3D printing takes concepts designed from CAD, and turns them into real objects. This technique allows for great accuracy and precision in product specifications while maintaining good overall strength. Unfortunately, this process is timely and comes at a high cost.

5.1.2 Balsa Wood

The more traditional method within the SAE competition is to use balsa wood to manufacture the spar and ribs. Balsa wood allows for the aircraft to remain at an overall minimal weight. This option also is very cheap and accessible, permitting possible extra spending in other parts of the aircraft. The downside of balsa comes from its lack of precision and accuracy within the manufacturing process.

5.1.3 Light Metals

The last option explores the use of light metals such as aluminum. A light metal thrives in its ability to withstand large moments produced by lift and drag. The high capability in strength may be a positive, but the high density of the light metal is a negative. The aircraft design must maintain a reasonable overall weight, however, if light metal ribs are used, this will be compromised.

5.2 Material Assessment

Proper assessment of the spar and rib material has been broken down into various criterions. The main criteria for the wing design are strength, weight, workability, and cost. Table 2 below shows a detailed decision matrix weighing each of the material selections against our chosen criterion.

Table 4: Spar and Rib Decision Matrix

Concept	Criteria				Score
	Strength	Weight	Workability	Cost	
Balsa	4	1	4	1	10
Polymer	2	3	1	3	9
Light Metal	1	5	4	4	14

This decision matrix concludes that the polymer spar and ribs generated through 3D printing would be the best approach. Balsa is still a viable option, and will still be considered until the group conducts further cost-benefit and yield strength analysis.

6. Loading Scheme

Another major consideration of the aircraft's design is to choose a payload configuration that will ensure maximum inflight stability as well as the accessibility that will enable a sixty second load and unload for the SAE oral presentation. For purposes of specific configuration selection, we've chosen to focus analysis towards payload accessibility and weight type.

6.1 Payload Bay Location

This design consideration discusses the location of the payload bay. This decision has a direct impact on the ease of loading the aircraft, the ability to locate the center of gravity precisely, and the location of the aircraft wings.

6.1.1 Top Loading

A payload bay located on top of the fuselage allows for very simple loading of the aircraft. Space becomes an issue with a Top loading scheme due to the wings being located at the top of the aircraft as well as the control components being located there. The idea of a one-piece wing is not compatible with a top loading scheme because access to the top of the fuselage would become restricted.

6.1.2 Bottom Loading

By loading the aircraft from the bottom of the fuselage, the issue of inverting the aircraft when loading arises. This specific disadvantage can be mitigated through either construction of a loading stand or through a well-rehearsed loading protocol. A primary advantage of this load scheme is the ability to utilize the space on the top of the fuselage for placement of the wings, which has been chosen as the optimal location in the above discussion. As a result, more space inside the fuselage is made available, which will allow the payload mechanism to be more precise in locating the center of gravity.

Table 5: Payload Bay Location Decision Matrix

Concept	Criteria			Score
	Load Speed/Ease of Loading	CG Location	Wing Location	
Top	1	2	2	5
Bottom	2	1	1	4

This decision matrix shows that the bottom location of the payload bay is the optimal choice in this design consideration.

6.2 Payload Type

This design consideration refers to the construction of the payload system, in particular the objects that will be used to add weight to the aircraft.

6.2.1 Plates

Using plate masses as payload is advantageous because their size allows the group to create fewer of them. Also, the frame that the payload would sit on is easy to integrate into the fuselage structure. However, since these masses are so much larger, the adjustability of the center of gravity is decreased with this type of system.

6.2.2 Washers

A loading scheme that utilizes washers allows the center of gravity to be placed more accurately, since the individual weights are smaller. However, the infrastructure required to implement this system is more difficult to manufacture and also decreases the group's ability to load the aircraft with speed and ease.

Table 6: Payload Type Decision Matrix

Concept	Criteria			Score
	Load Speed/Ease of Loading	Adjustability of CG Location	Ease of Manufacture	
Plates	1	2	1	4
Washers	2	1	2	5

This decision matrix shows that the method of loading the aircraft with plates is the preferred choice, though the difference between the two is small. This decision will likely be solidified once the fuselage is built and the materials are purchased.

7. Propeller Selection

Model aircraft propellers use a specific numbering system to classify the various propeller types. Aircraft propellers are specified by “Diameter X Pitch” given in inches, (an example of this would be a 12 X 5 propeller, which would have a diameter of 12 inches and a pitch of 5 inches). Pitch is defined as the distance a propeller would advance in a solid medium if turned one revolution. Below are the two configurations that are under consideration for this project; Low diameter high pitch and high diameter low pitch.

7.1 Low Diameter High Pitch

The first option of using a low diameter high pitch offers a lower thrust with a higher airspeed of the plane. The high airspeed of this configuration has a negative impact of the maneuverability of the aircraft and due to the restricted airspace for the turning of the plane. This is an important characteristic to consider.

7.2 High Diameter Low Pitch

The concept of a high diameter low pitch configuration offers a higher thrust with a low airspeed. Thrust is an important trait to consider for takeoff because it’s important in generating lift for the aircraft. Due to the low airspeed of this configuration Maneuverability is much easier for the aircraft.

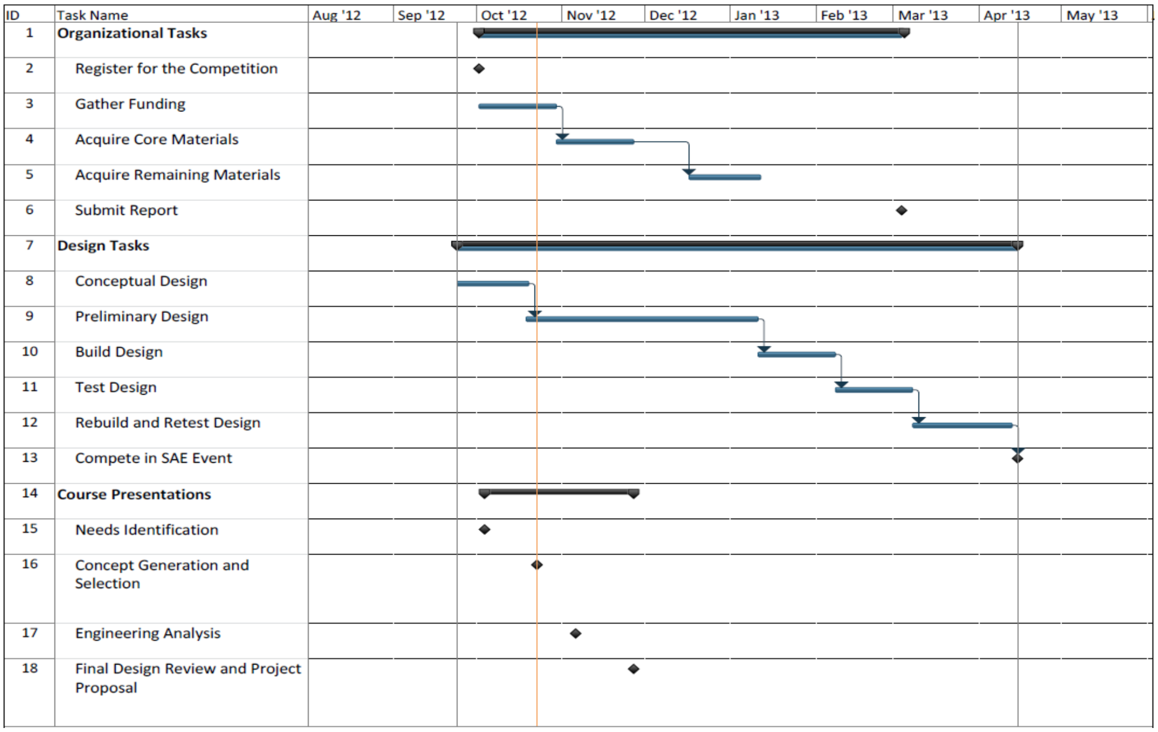
Table 7: Propeller Selection Decision Matrix

Concept	Criteria			Score
	Thrust	Airspeed	Maneuverability	
Low Diameter, High Pitch	3	1	3	7
High Diameter, Low Pitch	1	2	1	4

The design matrix above helped in determining that a high diameter low pitch configuration would best fit the design criteria for this project. The analysis and testing of a number of configurations of the High diameter low pitch will determine the final propeller for the aircraft.

8. Project Timeline

Shown is an updated (10/25/12) record of the activities that this team has already completed as well as future schedule deadlines and requirements. This timeline is derived from previous year's schedules and approximating the amount of time needed to complete specific tasks.



ID	Task Name
1	**Organizational Tasks**
2	Register for the Competition
3	Gather Funding
4	Acquire Core Materials
5	Acquire Remaining Materials
6	Submit Report
7	**Design Tasks**
8	Conceptual Design
9	Preliminary Design
10	Build Design
11	Test Design
12	Rebuild and Retest Design
13	Compete in SAE Event
14	**Course Presentations**
15	Needs Identification
16	Concept Generation and Selection
17	Engineering Analysis
18	Final Design Review and Project Proposal

This timeline indicates that we are presently meeting our schedule, with this report being the second major milestone for the lecture portion of the project. The team is currently finalizing conceptual designs and beginning material acquisition in preparation for a presentation of detailed mechanical analysis on November 5th.

9. Conclusion

As stated previously, aircraft design is a well-established science. As such, the focus of this project is to optimize each component of the aircraft using selection and configuration design processes. Design matrices were developed for the airfoil planform, wing and tail configurations, spar and ribs, loading schemes, and propeller selection. These matrices helped decided some factors, but also shows further analysis is necessary for optimal design selections. Further analysis also needs to be performed on the airfoil selection, static analysis, landing gear, maneuvering mechanisms, and control systems. These design considerations are secondary design concerns which are established through the base design of the aircraft. When detailed analysis is deemed adequate, formation of the final design will be determined for the aircraft.

References:

[1] Raymer, Aircraft Design: A Conceptual Approach
[2] Johnson, Airfield Models, http://airfieldmodels.com/
[3] Anderson, Fundamentals of Aerodynamics