# SAE Aero Design

## Concept Generation and Selection

Ali Alqalaf, Jasem Alshammari, Dong Yang Cao,
Darren Frankenberger, Steven Goettl, and John Santoro
Team 16

*Submitted towards partial fulfillment of the requirements for*

***Mechanical Engineering Design I – Fall 2015***

Department of Mechanical Engineering
Northern Arizona University
Flagstaff, AZ 86011

## Table of Contents

## 1. Introduction

The SAE Aero Design Capstone team has conducted research on the problem definition and project plan, and now moves onto concept generation and selection. The team began with recognizing which functionalities of the aircraft needed concepts to be developed and chosen. After these were recognized, criteria for each functionality were determined, then weighted based on importance. Multiple concepts were then developed for each functionality. These were compiled into decision matrices and then scored. These designs are not necessarily final, but a good idea of what the team wants to accomplish with the design of the aircraft.

## 2. Functional Diagram

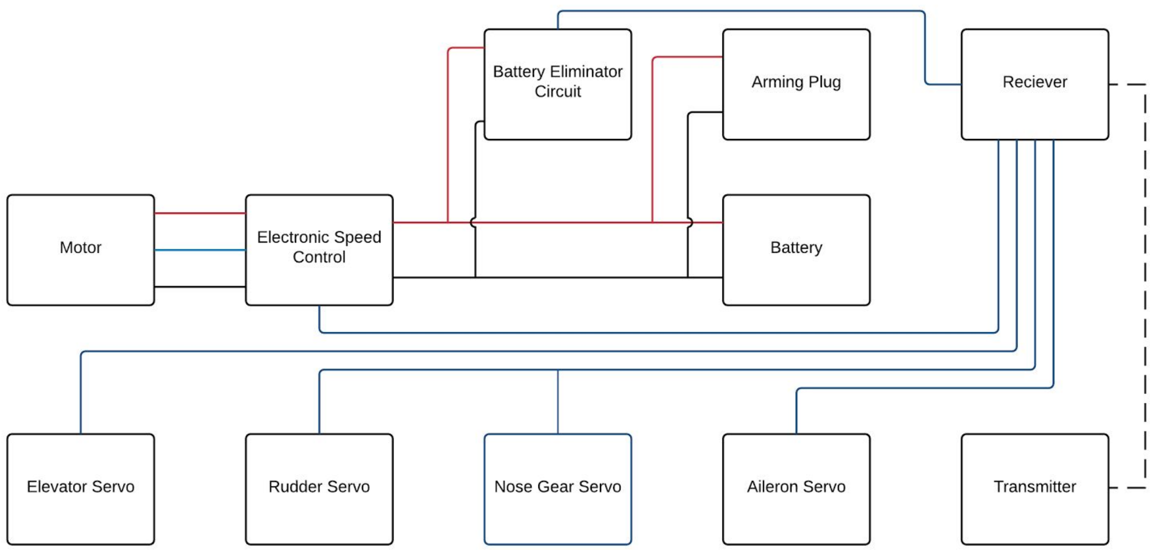



*Figure 1. Functional Diagram*

Shown above is the functional diagram for the electrical components of the aircraft. Red wires are positive, and black wires are negative. Blue wires denote servo wires. The battery is connected to the electronic speed control (ESC), which is then connected to the motor with a variable controller allowing for different power settings. The arming plug is connected to the battery as well, providing a killswitch. This is required by competition rules. Also wired to the battery is the battery eliminator circuit (BEC). Connected to the BEC is the receiver via a servo wire. This eliminates the need for a separate battery for the receiver. Configured to the receiver are the servos connected to the different control surfaces. The rudder servo and nose gear servo are connected via a y-harness, and one will be reversed giving the proper control to the user. There will be one elevator servo and two aileron servos connected to the receiver as well via a y-harness. Finally, the receiver is configured to the transmitter wirelessly via a 2.4 Ghz signal.

## 3. Relative Weights of Criteria

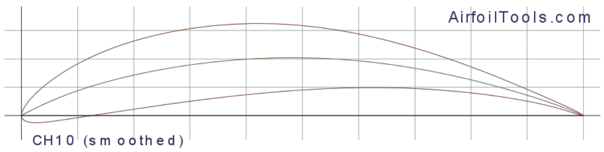
*Table 1. Relative Weights of Criteria - Landing Gear*

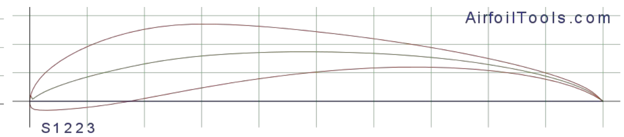
| Criteria | Weight | Strength | Coefficient of Drag | Control | Raw Total | Normalized Weights |
|---|---|---|---|---|---|---|
| Weight | - | 0 | 1 | 0 | 1 | **0.167** |
| Strength | 1 | - | 0 | 0 | 1 | **0.167** |
| Coefficient of Drag | 0 | 1 | - | 0 | 1 | **0.167** |
| Control | 1 | 1 | 1 | - | 3 | **0.5** |

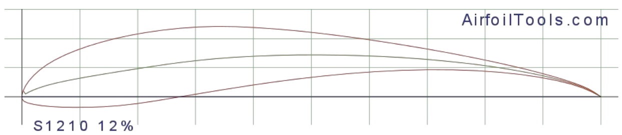
Illustrated above is one example of the relative weights of criteria, specifically for the landing gear decision matrix. The criteria are compared to each other, and ranked based on importance. Score are given as: 1 point if deemed more important, 0 points if deemed less important.  For example, weight in the left hand column was considered less important that strength, more important than coefficient of drag and less important than control. Weight, strength, and coefficient of drag each scored one point, meaning they were considered more important that at least one other criteria. Control scored 3 points as it was deemed the most important criteria in regards to the landing gear.

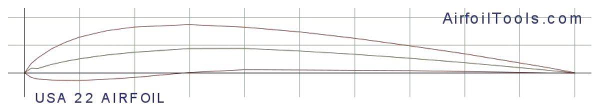
## 4. Concept Generation

### a. Airfoil




## Table 2. Airfoil Weighted Decision Matrix

| **Decision Factors** | | **S1223** | **CH 10** | **US A22** | **S1210** | | |
|---|---|---|---|---|---|---|---|
| **Criteria** | **Wt.** | **1** | **2** | **4** | **5** | **Criteria** | **Definition** |
| Coefficient of Lift (max) | 0.2 | 5 | 4 | 4 | 2 | Coefficient of Lift (max) | The airfoil with the highest maximum lift coefficient |
| Design Lift Coefficient | 0.1 | 4 | 3 | 2 | 2 | Design Lift Coefficient | The airfoil with the proper ideal or design lift coefficient |
| Coefficient of Drag (min) | 0.1 | 2 | 4 | 3 | 1 | Coefficient of Drag (min) | The airfoil with the lowest minimum drag coefficient |
| Lift to Drag Ratio | 0.3 | 5 | 2 | 5 | 5 | Lift to Drag Ratio | The airfoil with the highest lift-to-drag ratio |
| Lift Curve Slope (max) | 0.1 | 5 | 5 | 1 | 3 | Lift Curve Slope (max) | How much flexibility of site layout is possible without CSS and PHP code |
| Pitching Moment Coefficient | 0.1 | 4 | 2 | 2 | 2 | Pitching Moment Coefficient | The airfoil with the lowest (closest to zero; negative or positive) pitching moment coefficient |
| Stall Quality | 0.1 | 5 | 2 | 2 | 4 | Stall Quality | The proper stall quality in the stall region (the variation must be gentle, not sharp). |
| **Weighted Scores** | | 4.5 | 3.0 | 3.3 | 3.1 | | |

The decision matrix above shows the values that we gave each of the design for the criteria the team determined was most important.The team determined that the lift to drag ratio was most important with the maximum coefficient of lift coming in a close second. This was determined because the airfoil with best lift to drag ratio will be most effective for carrying a payload. The highest coefficient of lift combined with the highest lift to drag ratio will give us the best performing airfoil design. The airfoil that we chose based on the criteria was the S1223 airfoil.

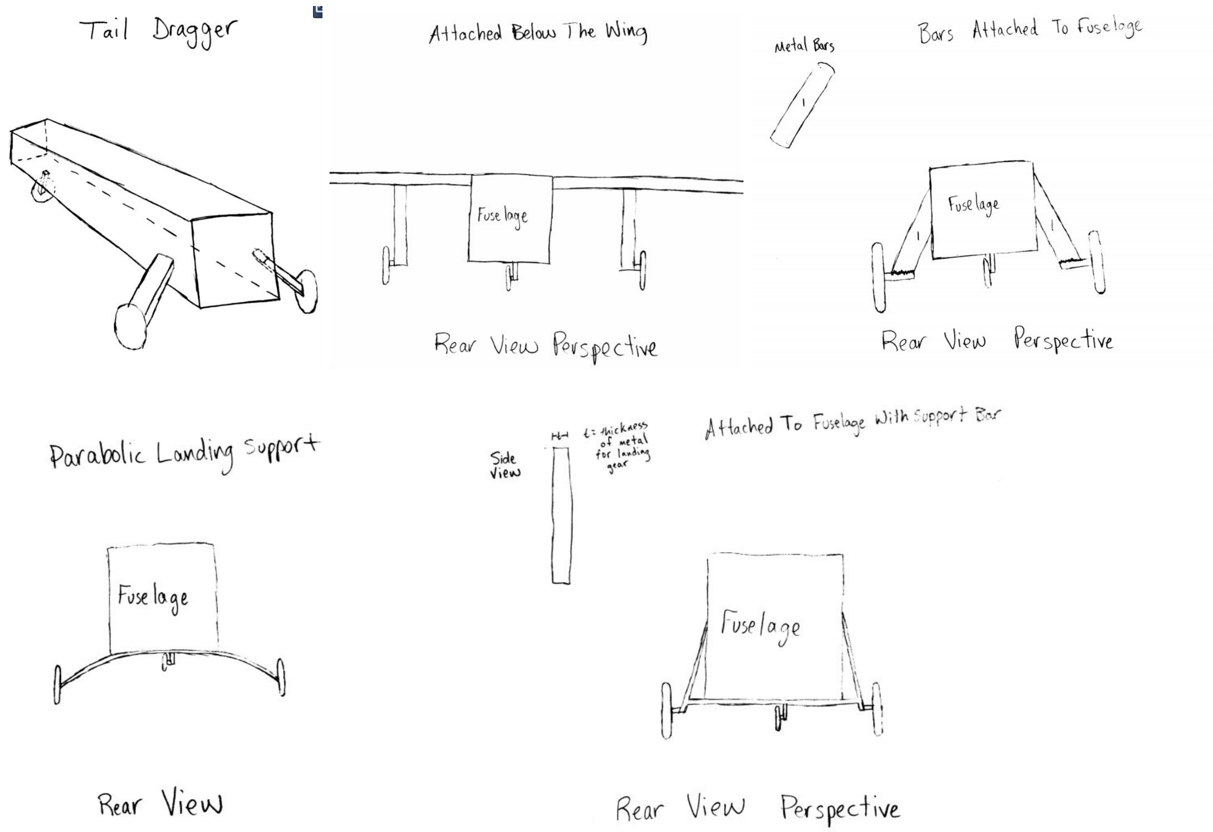
**b. Sweep and Taper Wing Configuration**

## Table 3. Sweep and Taper Wing Configuration Weighted Decision Matrix

| Decision Factors | | RECTANGLE | TAPER | DELTA | Which wing configuration do I use? | |
|---|---|---|---|---|---|---|
| Criteria | Wt. | 1 | 2 | 3 | Criteria | Definition |
| Weight | 0.2 | 3 | 4 | 3 | Weight | overall wing weight |
| loading | 0.2 | 4 | 3 | 3 | loading | Eases and facilitates the loading and unloading of loads and cargo into and out of cargo aircraft |
| Coefficient of Lift (max) | 0.2 | 5 | 4 | 3 | Coefficient of Lift (max) | The wing configuration with the highest maximum lift coefficient |
| Coefficient of Drag (min) | 0.2 | 3 | 4 | 3 | Coefficient of Drag (min) | The airfoil with the lowest minimum drag coefficient |
| Lift to Drag Ratio | 0.2 | 5 | 4 | 4 | Lift to Drag Ratio | The airfoil with the highest lift-to-drag ratio |
| Weighted Scores | | 4.0 | 3.8 | 3.2 | | |

The criteria that were deemed most important for the sweep and taper of the wings were: weight, loading, maximum coefficient of lift, minimum coefficient of drag, and lift-to-drag ratio. The rectangle beats out the other two designs as it as a higher lift-to-drag ratio, higher maximum coefficient of drag, and easier in loading and unloading.

## c. Landing Gear Configuration

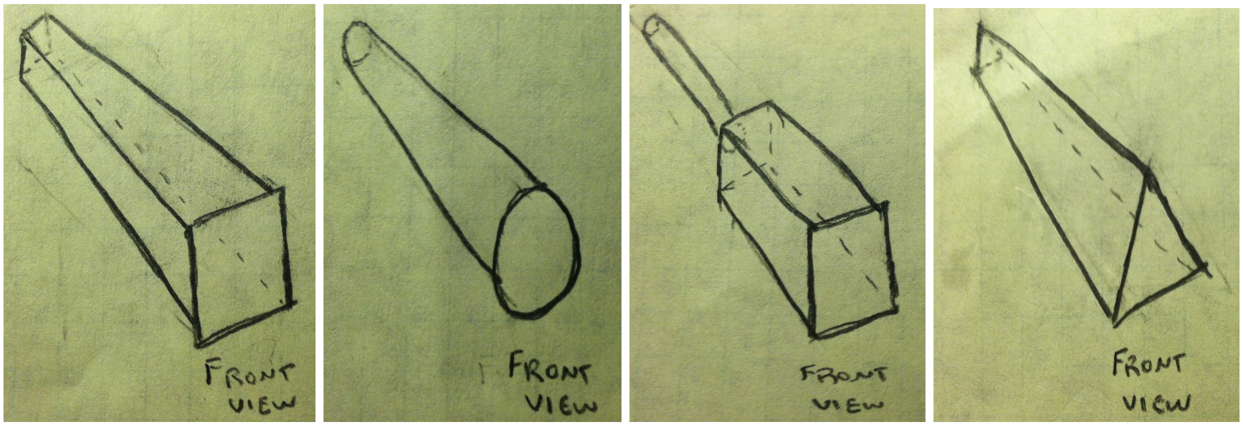


## Table 4. Landing Gear Configuration Weighted Decision Matrix

| Decision Factors | | Tail Dragger | Attached Below The Wing | Bars Attached To Fuselage | Parabolic Landing Support | Attached to Fuselage With Support Bar |
|---|---|---|---|---|---|---|
| Criteria | Wt. | 1 | 2 | 3 | 4 | 5 |
| **Weight** | 0.16 | **5** | **1** | **1** | **4** | **3** |
| **Strength** | 0.16 | **3** | **4** | **3** | **3** | **5** |
| **Coefficient of Drag** | 0.16 | **5** | **1** | **2** | **4** | **2** |
| **Control** | 0.5 | **1** | **5** | **4** | **2** | **4** |
| Weighted Scores | | **2.6** | **3.5** | **3.0** | **2.8** | **3.6** |

The decision matrix above shows the values that we gave each of the design for the criteria the team determined was most important. The team decided that the control of the aircraft on the ground was the most critical criteria. This was decided because the team wants to make sure the landing and takeoff will not be an issue at the competition. The team's advisor and mentor both told the team that other teams' aircrafts had crash landings which was the most common way for aircrafts to get eliminated. The criteria that gave the attached to fuselage with a support bar the edge on the other designs, is the strength and weight. These criterias are also critical because the strength is needed so that the landing gear does not collapse while landing.

**d. Fuselage Design**



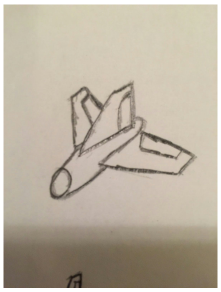

*(From left to right - Rectangular Prism, Cylindrical, Bar Design and Triangular Prism)*

**Table 5. Fuselage Design Weighted Decision Matrix**

| Decision Factors | | Rectangular Prism | Cylindrical | Bar Design | Triangular Prism | | |
|---|---|---|---|---|---|---|---|
| **Criteria** | **Wt.** | **1** | **2** | **3** | **4** | **Criteria** | **Definition** |
| Weight | 0.3 | 5 | 5 | 2 | 5 | Weight | Overall weight that the fuselage adds to the plane |
| Strength | 0.3 | 4 | 2 | 3 | 5 | Strength | How much force the fuselage design can have exerting on it before it breaks |
| Coefficient of Drag | 0.3 | 4 | 5 | 2 | 3 | Coefficient of Drag | The fuselage with the lowest minimum drag coefficient |
| Length | 0.1 | 5 | 4 | 3 | 4 | Length | The shortest fuselage the plane can have |
| **Weighted Scores** | | 4.4 | 4.0 | 2.4 | 4.3 | | |

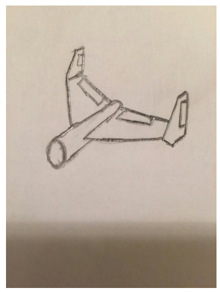
The fuselage is another critical design because it must keep drag to a minimum with also be strong with the least amount of weight and length. The less length the fuselage has, the more width we can give the wing which creates more lift. The strength, weight and coefficient of drag are weighted more because those criteria will affect the flight of the aircraft more than the length of the fuselage. The team decided that the length of the rectangular prism would be easier to minimize than the triangular prism design, while keeping the strength of the fuselage as well. The team also decided that the aircraft could get more volume with a rectangular prism which makes loading and unloading the payload bay much easier. The coefficient of drag was also less because the team believed the rectangular prism would have a more continuous airflow over the fuselage when it joins with the horizontal and vertical stabilizers.

### e. Vertical and Horizontal Stabilizers

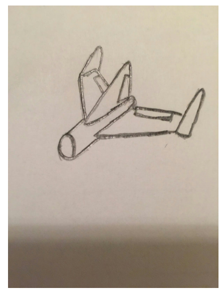


**Conventional Tail**

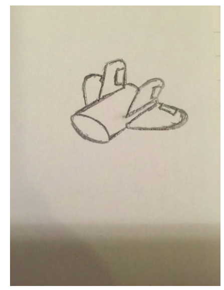
**T-tail**



**Dual Tail**



**Triple Tail**

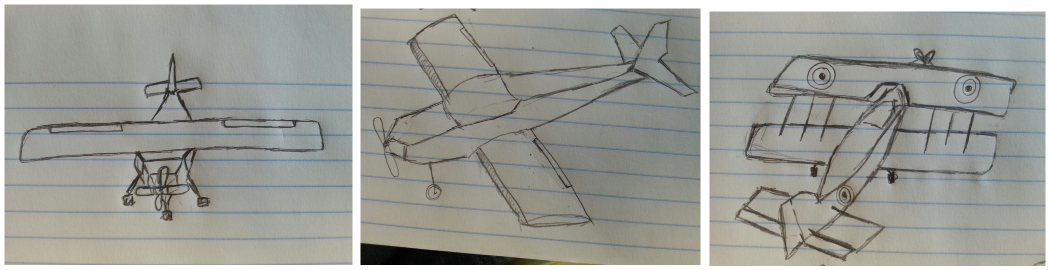


**Twin Tail**

| Table 6. Vertical and Horizontal Stabilizers Decision Matrix | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Decision Factors | | Conventional Tail | T-tail | Dual Tail | Triple Tail | Twin Tail | | |
| Criteria | Wt. | 1 | 2 | 3 | 4 | 5 | Criteria | Definition |
| Stability Coefficient | 0.30 | 4 | 3 | 3 | 3 | 4 | Stability Coefficient | The higher the stability coefficient, the straighter the airplane will move |
| pitching control (up and down) | 0.25 | 4 | 4 | 3 | 2 | 4 | pitching control (up and down) | The horizontal stabilizer prevent up and down motion of the nose of the airplane |
| yaw control (right and left) | 0.25 | 4 | 4 | 3 | 3 | 5 | yaw control (right and left) | The vertical stabilizer prevent the airplane from swinging side to side |
| Weight | 0.20 | 4 | 4 | 3 | 2 | 3 | Weight | The weight of the tail |
| Weight Scores | | 4.0 | 3.7 | 3.0 | 2.6 | 4.1 | | |

The decision matrix above shows the design scores for vertical and horizontal stabilizers. The stabilizers job is to pitch (up and down) and yaw (right and left) the airplane. The twin tail design wins because it is more stable than most of the other tails. Furthermore, having two vertical stabilizers will help in being more effective upon other tails in yawing. Also, the height is cut in half if one was to use just one vertical stabilizer.

### f. Wing Placement Configuration



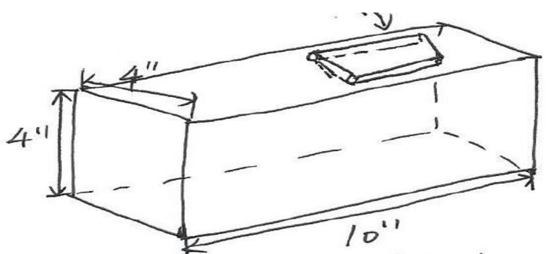
***(From left to right- Monowing High Placement Monowing Low Placement Biplane)***

## Table 7. Wing Placement Configuration Weighted Decision Matrix

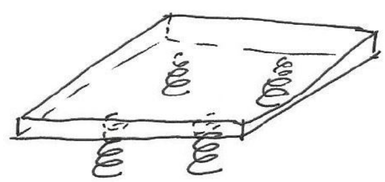
| Decision Factors | | Monowing Low Placement | Monowing High Placement | Biplane | | |
|---|---|---|---|---|---|---|
| **Criteria** | **Wt.** | **1** | **2** | **3** | **Criteria** | **Definition** |
| Weight | 0.1 | 5 | 4 | 2 | Weight | overall wing weight |
| Loading | 0.1 | 4 | 5 | 3 | loading | Eases and facilitates the loading and unloading of loads and cargo into and out of cargo aircraft |
| Coefficient of Lift (max) | 0.2 | 5 | 4 | 5 | Coefficient of Lift (max) | The wing configuration with the highest maximum lift coefficient |
| Coefficient of Drag (min) | 0.2 | 4 | 5 | 3 | Coefficient of Drag (min) | The airfoil with the lowest minimum drag coefficient |
| Lift to Drag Ratio | 0.4 | 4 | 5 | 2 | Lift to Drag Ratio | The airfoil with the highest lift-to-drag ratio |
| **Weighted Scores** | | 4.3 | 4.7 | 2.9 | | |

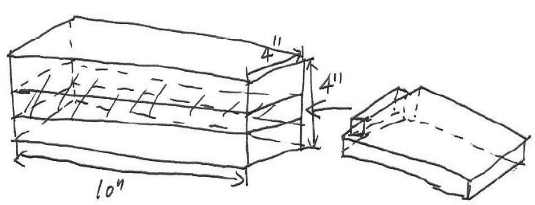
Based on the criteria, the top two designs were the monowing high and low placement. Low placement beats the high wing placement slightly in weight and maximum coefficient of lift. The high placement design beats out the low placement design, because it offers a smaller coefficient of drag, higher lift-to-drag ratio, and ease of loading.

### g. Payload Configuration

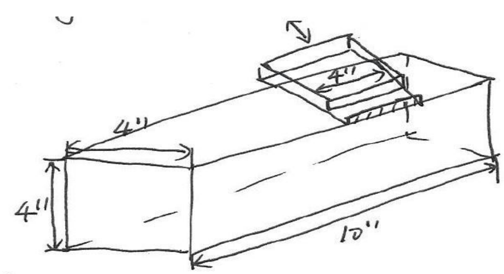


design 1: box hinged Lid.


design 2: spring Load plate.



design3: removeable center seam box.



design4: box sliding lid.

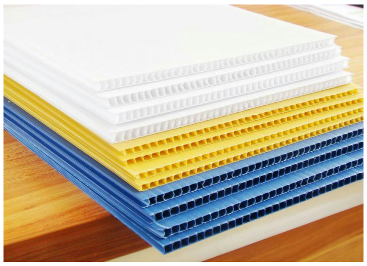
**Table 8. Payload Configuration Weighted Decision Matrix**

| Decision Factors | | Box w/ Hinged Lid | Spring Loaded Plates | Removable Center Seam Box | Box w/ Sliding Lid | | |
|---|---|---|---|---|---|---|---|
| Criteria | Wt. | 1 | 2 | 3 | 4 | Criteria | Definition |
| Payload (max) | 0.15 | 3 | 3 | 3 | 3 | Payload (max) | Overall payload weight |
| Weight | 0.40 | 3 | 2 | 1 | 4 | Weight | Total weight of configuration |
| Cost | 0.30 | 2 | 1 | 3 | 2 | Cost | Cost of payload configuration |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | material |
| **Ease of Construction** | 0.15 | **4** | **1** | **3** | **4** | **Ease of Construction** | **Time required to construct** |
| Weighted Scores | | **2.9** | **1.7** | **2.2** | **3.3** | | |

Shown above are the payload configuration design concepts. Also above, is the decision matrix for the payload configuration. The payload configuration holds the payload in place in the fuselage. In terms of criteria, weight was deemed the most important, followed by cost, and payload and ease of construction. Design option 1 and design option 4 were the two highest ranking designs. Design option 4, the box with the sliding lid as it slightly edged option 1 in regards to weight and cost.

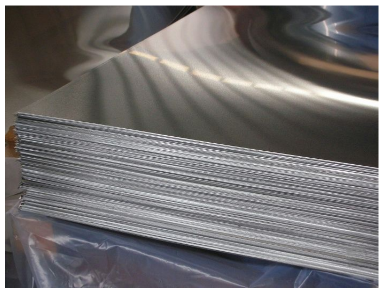
### h. Material Comparison



Design 1: Plastic http://www.aliexpress.com

Design 2: Wood https://commons.wikimedia.org

Design 3: foam http://forums.sjgames.com



Design 4: Aluminum http://www.omnisteelsupply.com

## Table 9. Material Comparison Weighted Decision Matrix

| Decision Factors | | Plastic | Wood | Foam | Aluminium | | |
|---|---|---|---|---|---|---|---|
| Criteria | Wt. | 1 | 2 | 3 | 5 | Criteria | Definition |
| Weight | 0.20 | 5 | 4 | 5 | 4 | Weight | Overall material weight |
| Strength | 0.20 | 3 | 3 | 2 | 4 | Strength | Strong or weak |
| Material formation | 0.20 | 2 | 4 | 4 | 2 | Material formation | The strength needed to format the material |
| Cost | 0.40 | 3 | 5 | 4 | 4 | Cost | Cost of the material |
| Weighted Scores | | 3.2 | 4.2 | 3.8 | 3.6 | | |

The decision matrix above shows the criteria of the material the team is going to use for a majority of the airplane parts. In regards to material selection, strength, cost, weight, and formation are all important factors. The wood has the highest scoring material. It is easy to form, cheap, and has good strength.

**i. Receiver**

*design 1, 2, 3: www.spektrumrc.com*

**Table 10. Receiver Weighted Decision Matrix**

| Decision Factors | | 4 Channel Aircraft Receiver | 6 Channel Aircraft Receiver | 7 Channel Aircraft Receiver | | |
|---|---|---|---|---|---|---|
| Criteria | Wt. | 1 | 2 | 3 | Criteria | Definition |
| weight | 0.3 | 5 | 5 | 0 | weight | The receiver with the minimum weight |
| loading | 0.2 | 3 | 3 | 2 | loading | The receiver with minimum loading |
| time period recorded | 0.2 | 5 | 5 | 5 | time period recorded | The receiver with the suitable time period recorded |
| altitude recorded | 0.2 | 4 | 5 | 4 | altitude recorded | The receiver with the expected altitude recorded |
| Quality | 0.1 | 5 | 4 | 5 | Quality | The receiver should be with the best quality |
| Weighted Scores | | 4.2 | 4.3 | 2.5 | | |

The decision matrix above shows the design scores of the receiver selection. The team decided that the most important criteria is the weight of the receiver, with loading time period recorded, altitude recorded and quality following. Based on these criteria and the scorings, the team will use a 6 channel aircraft receiver.

### j. Transmitter

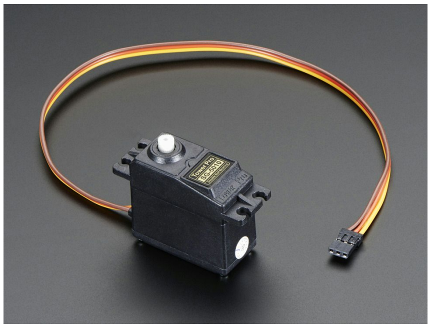

*design 4, 5, 6: www.spektrumrc.com*

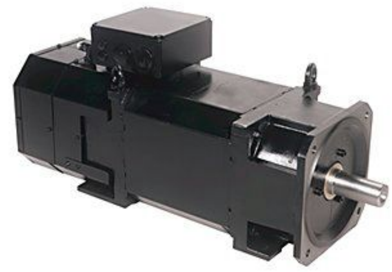
## Table 11. Transmitter Configuration Weighted Decision Matrix

| Decision Factors | | 5 channel Transmitter | 6 channel transmitter | 7 channel transmitter | Which transmitter do I use? | |
|---|---|---|---|---|---|---|
| Criteria | Wt. | 1 | 2 | 4 | Criteria | Definition |
| Weight | 0.2 | 4 | 1 | 5 | Weight | overall transmitter weight |
| loading | 0.3 | 2 | 0 | 0 | loading | transmitter loading should be as small as possible |
| attenuate transmit signal | 0.2 | 5 | 3 | 3 | attenuate transmit signal | the transmitter should transmit suitable signal to the radio station |
| gains | 0.1 | 5 | 5 | 5 | gains | the ability of gaining signals |
| losses | 0.2 | 3 | 4 | 1 | losses | the ability of losses signals |
| Weighted Scores | | 3.5 | 2.1 | 2.3 | | |

This is our team transmitter decision matrix. The criteria are compared to each other, and ranked based on importance. I choose different channels of transmitter to see how it going to fit the decision factors. Our group consider the 5 channel transmitter is the most suitable choice. because it good at signal gains and losses which is most important criteria in this part of design. Then the transmitter will send the signal to the radio station. Good signal transmission will make sure that our project is able to fly safety.

**k. Servo**



| Table 12. Servo Decision Matrix | | | | | | |
|---|---|---|---|---|---|---|
| Decision Factors | | Standard servo | RC servo | high power servo | | |
| Criteria | Wt. | 1 | 2 | 3 | Criteria | Definition |
| Torque coefficient | 0.3 | 3 | 0 | 5 | Torque coefficient | The higher the torque coefficient the better the servo is |
| Speed | 0.2 | 3 | 3 | 5 | Speed | The faster the speed is the butter servo |
| Size | 0.2 | 0 | 0 | 4 | Size | to fit the plane |
| Voltage | 0.3 | 0 | 3 | 5 | Voltage | higher the voltage leads to faster servo movement and more power |
| Weighted Scores | | 1.5 | 1.5 | 4.8 | | |

In the decision matrix for the servo shown are the different criteria: torque coefficient, speed, size, and voltage. Also shown are the design concepts. From there, the team chose the torque coefficient and the size are the criteria that were to be focused on because the torque coefficient will decide how powerful the handling will be and for the size the team is committed to certain area specialty with the wing.

**l. Speed Controller**


**Table 13. Speed Controller Decision Matrix**

| Decision Factors | | ESC:B500 3D/X | ESC,EC5 (V2) | 12S MAX HEAVY DUTY BEC | | |
|---|---|---|---|---|---|---|
| Criteria | Wt. | 1 | 2 | 3 | Criteria | Definition |
| voltage coefficient | 0.3 | 0 | 3 | 5 | voltage coefficient | coefficient of receiver battery |
| current coefficient | 0.2 | 5 | 0 | 3 | current coefficient | the larger the current coefficient the more power can handle |
| speed stability | 0.3 | 0 | 3 | 5 | speed stability | control force to hold the airplane in certain |
| speed option | 0.2 | 5 | 5 | 5 | speed option | to have the the variety of speed |
| Weighted Scores | | 2.0 | 2.8 | 4.6 | | |

The criteria that was chosen for the speed controller are: voltage coefficient, current coefficient, speed stability, and speed option. The speed stability was deemed to be the most important criteria, as it assists in controlling the airplane. Based on the decided criteria and weights, the determined speed controller that the team will use is a 12S max heavy duty BEC.

**m. Motor Size**


## Motor Size Weighted Decision Matrix x

| Decision Factors | | Brushed | Brushless | Which wing configuration do I use? | |
|---|---|---|---|---|---|
| Criteria | Wt. | 1 | 2 | Criteria | Definition |
| Weight | 0.10 | 3 | 4 | Weight | Overall weight that the motor adds to the plane |
| Thrust | 0.30 | 3 | 5 | Thrust | The amount of reaction force that the motor can create using the propeller |
| Thrust to Weight Ratio | 0.40 | 4 | 4 | Thrust to Weight Ratio | The ratio between how much weight the motor adds to how much thrust it creates |
| Control | 0.20 | 3 | 4 | Control | How easy the pilot can control the plane's speed |
| Weighted Scores | | 3.4 | 4.3 | | |

The brushless motor is necessary because the control and thrust to weight ratio are better than the brushed motor. The brushed motor just does not produce enough control or thrust which makes the brushless motor much better for the aircraft. The brushless motor is significantly more efficient than the brushed motor and that is why is performed better in the decision matrix.

## 5. Updated Project Plan

Table 2: Updated Project Plan

| Task | W 1 | W 2 | W 3 | W 4 | W 5 | W 6 | W 7 | W 8 | W 9 | W 10 | W 11 | W 12 | W 13 | W 14 | W 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Client meeting | | ■ | | | | | | | | | | | | | |
| Define problem and layout project plan | | | ■ | ■ | | | | | | | | | | | |
| Research design | | | ■ | ■ | | | | | | | | | | | |
| Research protocol writing | | | ■ | ■ | | | | | | | | | | | |
| Research parts of design | | | | | ■ | | | | | | | | | | |
| Functional diagram | | | | | ■ | ■ | ■ | | | | | | | | |
| Concept Generation | | | | | ■ | ■ | | | | | | | | | |
| Decision Matrix | | | | | | ■ | ■ | ■ | | | | | | | |
| Sketch Parts | | | | | | | | ■ | | | | | | | |
| Pick a final design (decision matrix) | | | | | | | | | ■ | ■ | ■ | | | | |
| Proof of Concept Discussion | | | | | | | | | | | ■ | ■ | | | |
| Project Proposal Discussion | | | | | | | | | | | | | ■ | | |
| Finalize design | | | | | | | | | | | | | ■ | ■ | ■ |
| Problem Definition and Project Plan Presentations | | | | ◆ | | | | | | | | | | | |
| Concept Generation and Selection Presentations | | | | | | | ◆ | | | | | | | | |
| Proof of Concept Demonstrations | | | | | | | | | | | | ◆ | | | |
| Project Proposal Presentations | | | | | | | | | | | | | | | ◆ |

In the updated project plan multiple tasks have been added. The team is on track to finish these tasks. Currently, every task has been finished up to week 8. Following week 8, the team will focus on picking a final design for the wings, as well as roughly calculate the center of gravity of the aircraft based on certain assumptions. The team must test and build a viable set of wings by week 12. After this is finished, the team will compile all research done this semester and provide a report and presentation, completing the project plan.

## 6. Conclusions

The team has made the final decisions on many of the critical aspects for the aircraft. This is shown in decision matrices and conceptual drawings. The Airfoil that was decided best fit for the aircraft is S1223, this is because, has the best critical factors such as lift and stall quality. For the sweep and taper configuration the winning design was the rectangle. This is because the other designs are efficient when an aircraft is moving much faster than the aircraft we are building. The landing gear configuration that is attached to fuselage with supporting bar is the best alternative due to the strength and control that the aircraft will have in the landing and taking off part of the competition. A fuselage was very close in the end, but the team thought the strength and ability in changing the size easily put the rectangular prism design above the rest. The aircraft's stability is critical for flight so the team decided to use the twin tail design, so that the height can be minimized with the same amount of control surfaces. When deciding the wing placement we determined for the coefficients of drag and lift that we need from the design, the monowing high placement was best to lift our aircraft. The lightest and best accessibility for the payload configuration was the box with a sliding lid. There will be two types of material that will be used to build different parts of the aircraft and the team chose wood and plastic. With all the types of receivers the team concluded that the 6 channel receiver would have enough channels for what is needed on our aircraft. The team also chose to use the 5 channel transmitter because it has more than enough gains to send signals to our receiver. The high powered servo was decided on because the aircraft must be responsive in the wind and the high powered servo will ensure this. For the speed controller the 12s max heavy duty is necessary for the speed stability it has. Due to how critical the weight, thrust and control is for the motor it is necessary that we use a brushless motor for our aircraft. All of these critical designs will be implemented into the aircraft and be modified as needed.

## 7. References


[1] *What-When-How, "Tail design", Conventional Tail, T-tail, Dual Tail, Triple Tail and Twin Tail. Available: what-when-how.com.*

[2] *National Aeronautics and Space Administration, "structures and materials", aircraft background, P3-4.*

[3] *P. J. Pritchard, Introduction to Fluid Mechanics 8th Edition. Fox and McDonald. Wiley, 2011.*

[4] *M. H. Sadraey, Aircraft design: a systems engineering approach. Hoboken, New Jersey: Wiley, 2012.*

[5] *"Airfoil Tools," Airfoil Tools. [Online]. Available at: http://airfoiltools.com/. [Accessed: 2015].*