SAE Aero Design

Project Proposal

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Team 16

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1) Introduction

The SAE Aero Design Competition is an event that is held annually for college students. Teams from all over the country gather and compete in three unique classes: Regular, Micro, and Advanced. The capstone team is tasked with the design and construction of an airplane that adheres to the requirements of the Regular class competition. There are many constraints that the competition has to make the task complex and difficult. The competition provides a chance for engineering students to learn something about designing and building a product and having fun while doing it. Most learning has been done in the classroom, so this project gives engineering students the chance to get hands on experience which will help in the future for the engineering profession. This report includes the problem definition and concept generation, as well as a project proposal with a finalized wing design, a tail design, final components, and a bill of materials.

2) Need Statement

Northern Arizona University does not have an airplane design to compete in the SAE Aero design competition, so the team is tasked with the design and construction of the airplane.

3) Project Goals

The goal of this project is to design and build an airplane that satisfies all SAE Aero design competition requirements and bring it to competition. It is important to aim high when setting goals, so the team will aim to win the SAE Aero Regular class competition. This project will be very educational in the manufacturing process, as well as the design aspects that will be needed to complete the airplane. Writing a report and orally presenting the final product is required, so the team will compile an exceptional report and presentation detailing the design and manufacturing processes.

4) Objectives

Table 1 - Objectives

Objective	**Measurement**	**Unit of Measurement**
Carry max payload	Weight	Force pounds (lb)
Carry a payload from point A to B	Distance	Feet (ft)
Small turning radius	Distance	Feet (ft)

Table 1 contains the objectives that the team has decided are critical for the project. Carrying a max payload is important as the competition adheres to teams that can lift the most weight. To complete a circuit and get a score in the competition, the payload must be moved from one point to another. A small turning radius for the aircraft allows for faster circuit completion resulting in a higher score in the competition.

5) Constraints

1. Aircraft Dimension Requirement

The dimension must not exceed 175 inches [1].

2. Material and Equipment Restrictions for Regular Class

The use of Fiber – Reinforced plastic (FRP) is not allowed, except in the motor mount, propeller, landing gear and control linkage component. Also, not allowed is the use of rubber bands to make the wing retain to fuselage. Furthermore, any types of gyroscopic or other stability assistance are not allowed [1].

3. Aircraft System Requirements

The airplane requires the use of a electric single motor, gearboxes, belt drive systems, and propeller shaft extensions are allowed in tow condition (one-to-one propeller to motor RPM should be maintained) and the prop(s) must rotate at motor RPM [1]. The battery should have: 6 cell (22.2 volt) Lithium Polymer (Li-Poly/Li-Po) battery pack. The minimum requirements for Li-Po battery are: 3000 mAh, 25c) and homemade batteries are prohibited [1]. A 2015 version 1000 watt power limiter from the SAE supplier is required and supplied by Neumoters.com [1]. For the radio system the battery should have a minimum capacity of 1000 mAh [1].

4. Payload Requirements

For the payload, the team will focus on the interior dimension and we must follow the requirements in Table 2 [1].

Table 2 - Length Width Height Tolerance For Payload Bay

Length	Width	Height	Tolerance
10.00	4.00”	4.00”	+ 0.125”, - 0.000”

The airplane should have one or more removable access for the payload bay. The payload interior surfaces have to be unbroken and smooth. The payload must also be secured to the airframe, as well as contain payload plates. The only penetrations are allowed in the payload bay surfaces is □payload support assembly. The support assembly for the payload must be removable and the bay will never considered as payload [1].

5. Other Requirements

The airplane must take off within a maximum distance of 200 ft. Likewise, the airplane must land within a maximum distance of 200 ft. Also, the time to complete all aerial tasks must be no more than 180 seconds [1].

6. Quality Function Deployment and House of Quality

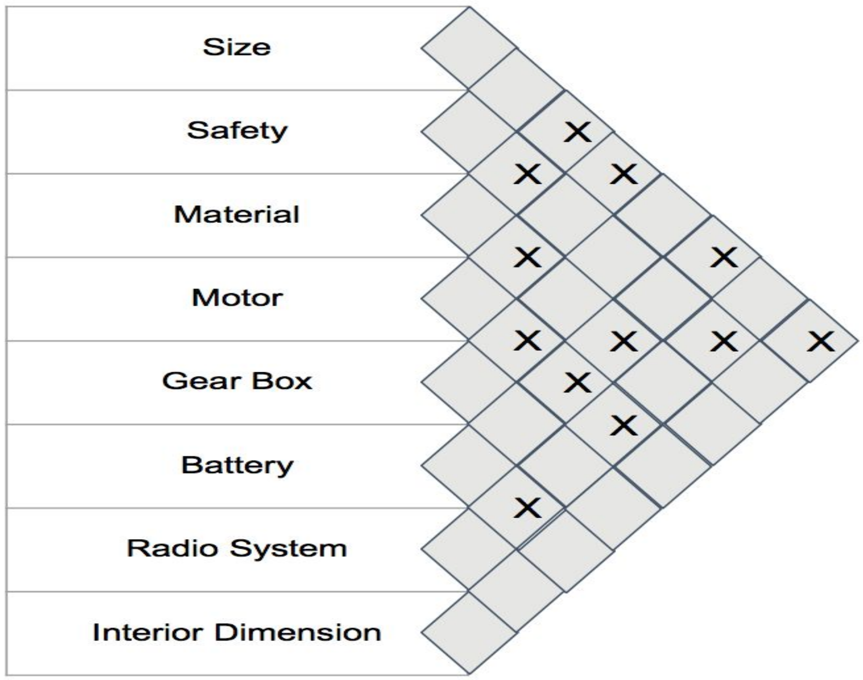
In Table 3 below, compared are the regular class design requirements with engineering requirements. These comparisons are given a score, then the engineering requirements are ranked by importance. Safety, material and motor were found to be the most important.

Table 3: Quality Function Deployment

Regular Class Design Requirements	Weights	Size	Safety	Material	Motor	Gear Box	Battery	Radio System	Interior Dimension
AIRCRAFT DIMENSION REQUIREMENT	5	9	1	0	0	1	0	0	9
MATERIAL AND EQUIPMENT RESTRICTIONS FOR REGULAR CLASS	5	3	9	9	9	1	3	3	1
AIRCRAFT SYSTEM REQUIREMENTS	5	3	9	3	9	1	9	9	0
PAYLOAD REQUIREMENTS	5	3	3	9	3	1	3	0	9
	Raw score	90	110	105	105	20	75	60	95
	Scaled	1	1	1	1	1	1	1	1
	Relative Weight	14%	17%	16%	16%	3%	11%	9%	14%
	Rank	5	1	2	2	8	6	7	4

In the house of quality, Table 4 below, the team took the engineering requirements from the Quality Function Deployment, Table 3, above to compare them with each other. The comparison will help the team know which requirements are related with the others.

Table 4: House of Quality



6) Functional Diagram

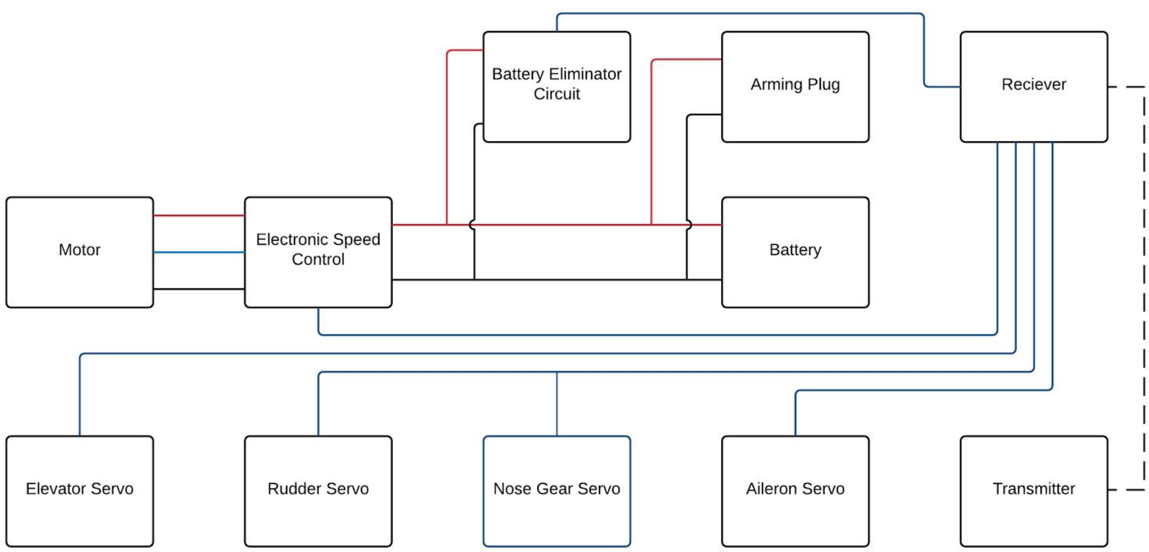
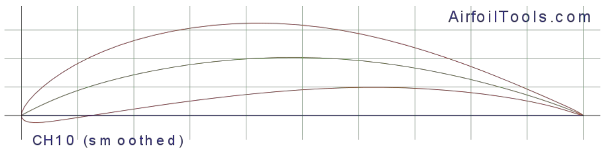


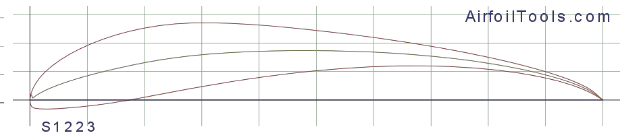
Figure 1. Functional Diagram

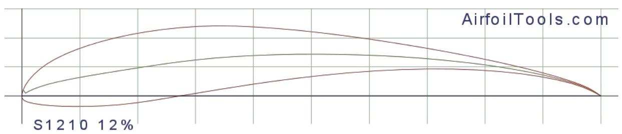
Shown above is the functional diagram for the electrical components of the aircraft. Red wires are positive, and black wires are negative. Blue wires denote servo wires. The battery is connected to the electronic speed control (ESC), which is then connected to the motor with a variable controller allowing 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.

7) Concept Generation

a. Airfoil







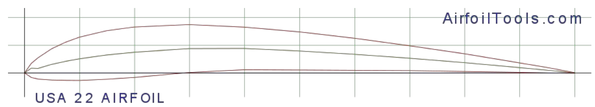


Table 4. Airfoil Weighted Decision Matrix

Decision Factors		**S1223**	**CH10**	**USA22**	**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.

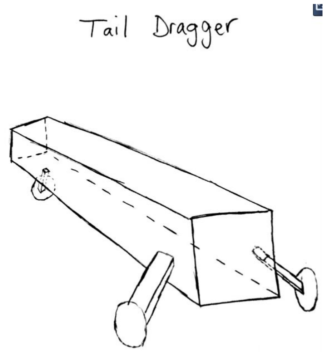
b. Sweep and Taper Wing Configuration

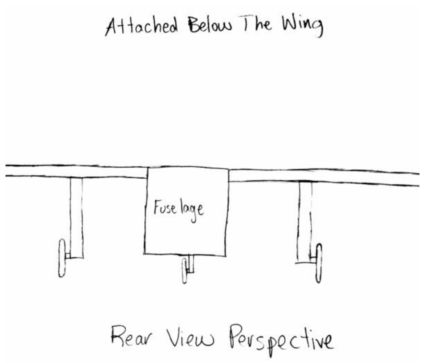
Table 5. Sweep and Taper Wing Configuration Weighted Decision Matrix

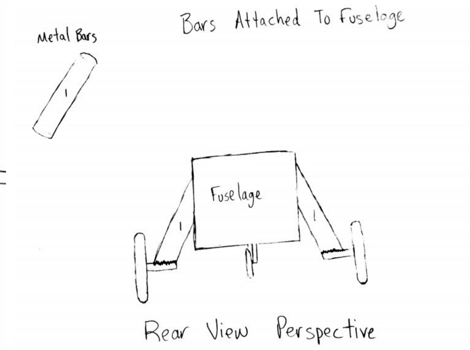
Decision Factors		RECTANGLE	TAPER	DELTA	Which wing configuration do I use?	
Criteria	Wt.	1	2	3	Criteria	Definition
Weight	0.2	3	4	3	Weight	overall wing weight
loading	0.2	4	3	3	loading	Eases and facilitates the loading and unloading of loads and cargo into and out of cargo aircraft
Coefficient of Lift (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		

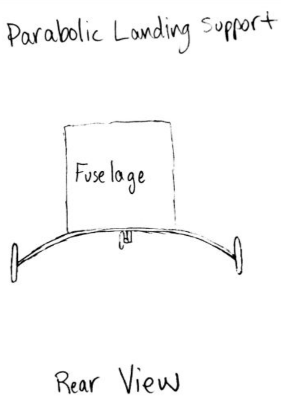
The criteria that were deemed most important for the sweep and taper of the wings were: weight, loading, maximum coefficient of lift, minimum coefficient of drag, and lift-to-drag ratio. The rectangle beats out the other two designs as it as a higher lift-to-drag ratio, higher maximum coefficient of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

c. Landing Gear Configuration









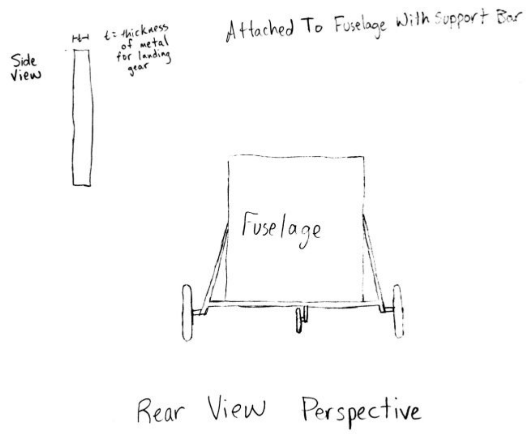
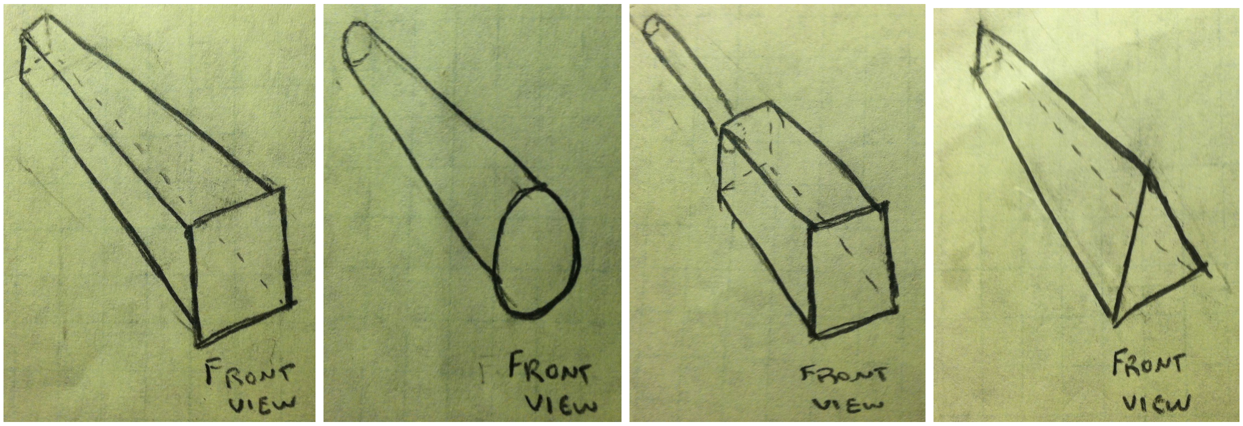


Table 6. Landing Gear Configuration Weighted Decision Matrix

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



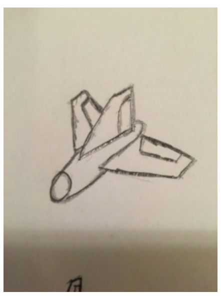
(From left to right - Rectangular Prism, Cylindrical, Bar Design and Triangular Prism)

Table 7. 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		

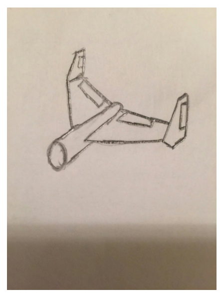
The fuselage is another critical design because it must keep drag to a minimum with also be strong with the least amount of weight and length. The less length the fuselage has, the more width we can give the wing which creates more lift. The strength, weight and coefficient of drag are weighted more 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

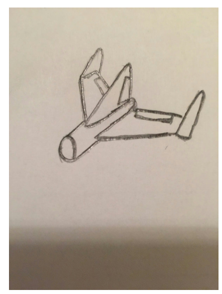


Conventional Tail

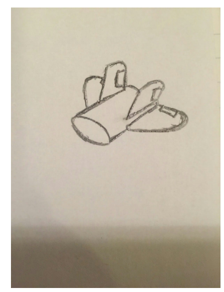
T-tail



Dual Tail



Triple Tail

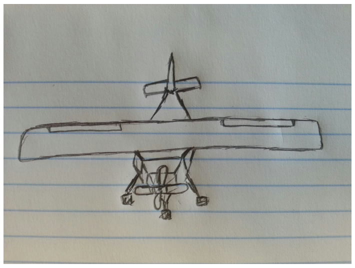
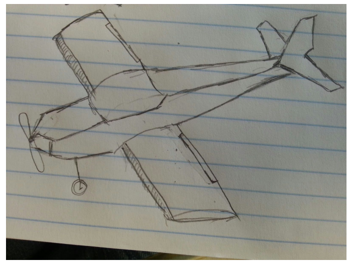
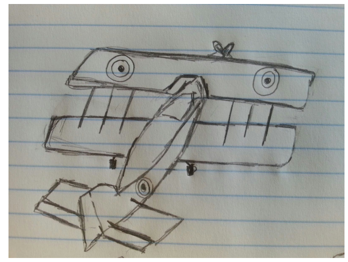


Twin Tail

Table 8. 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

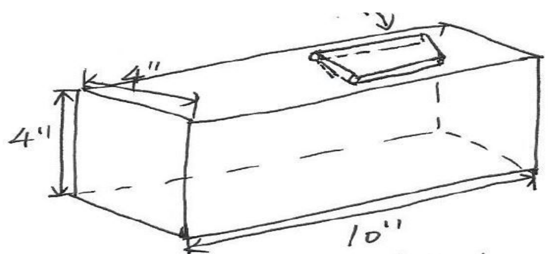
(From left to right- Monowing High Placement Monowing Low Placement Biplane)

Table 9. Wing Placement Configuration Weighted Decision Matrix

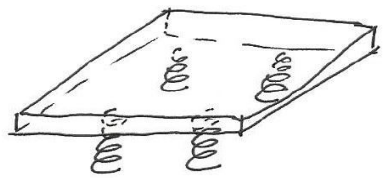
Decision Factors		Monowing Low Placement	Monowing High Placement	Biplane		
Criteria	**Wt.**	**1**	**2**	**3**	**Criteria**	**Definition**
Weight	0.1	5	4	2	Weight	overall wing weight
Loading	0.1	4	5	3	loading	Eases and facilitates the loading and unloading of loads and cargo into and out of cargo aircraft
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.

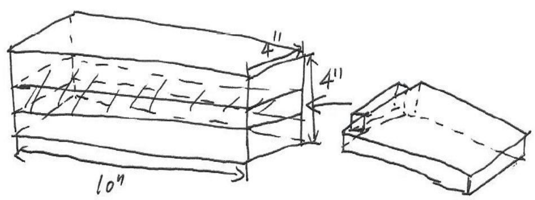
g. Payload Configuration



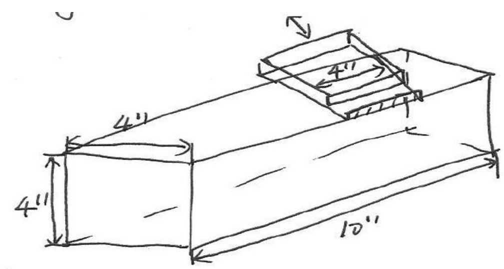
design 1: box hinged Lid.



design 2: spring Load plate.



design3: removeable center seam box.



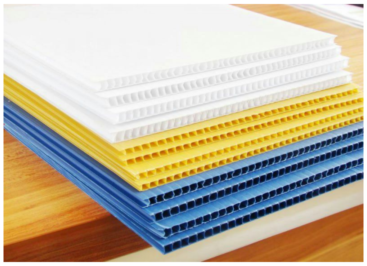
design4: box sliding lid.

Table 10. 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.

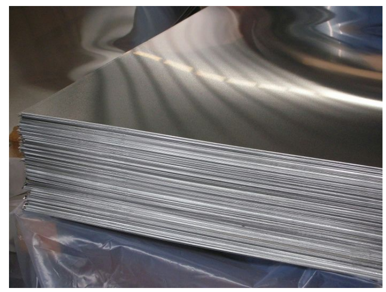
h. Material Comparison



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 11. 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 12. 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

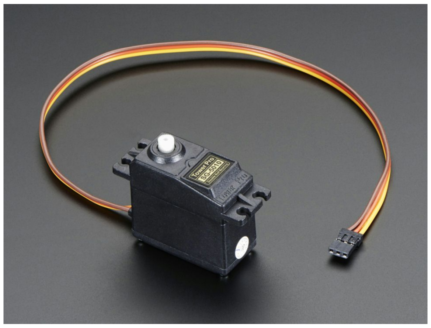
Table 13. Transmitter Configuration Weighted Decision Matrix

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



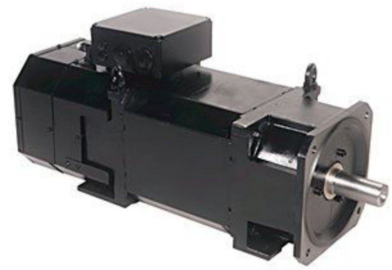


Table 14. Servo Decision Matrix

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 15. Speed Controller Decision Matrix						
Decision Factors		ESC:B50 0 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.

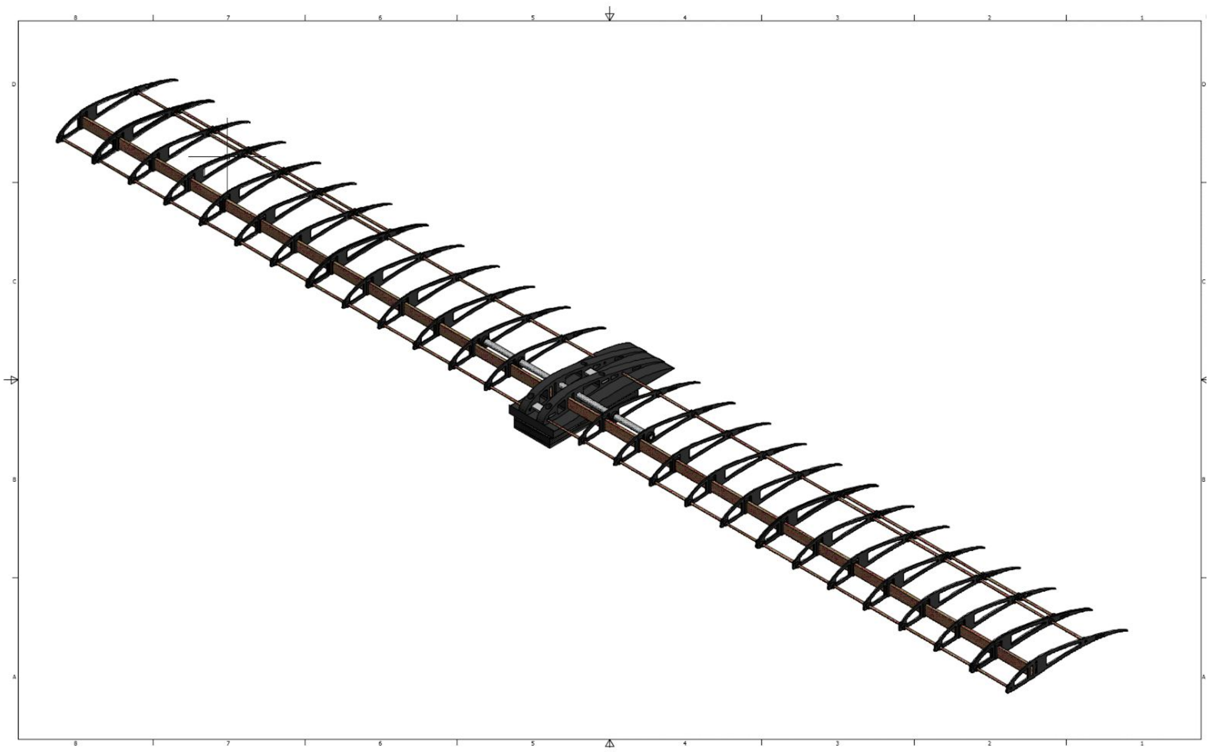
m. Motor Size

Table 16. Motor Size Weighted Decision Matrix

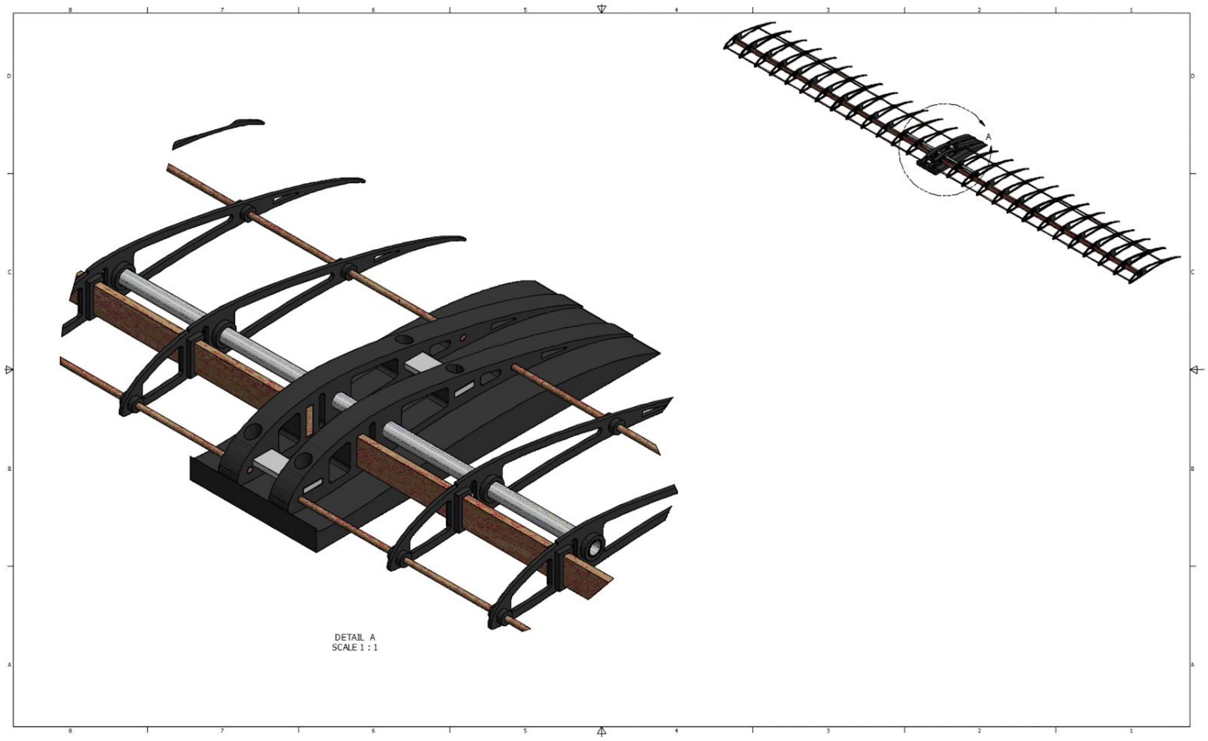
Decision Factors		Brushe d	Brushless	Which wing configuration do I use?	
Criteria	Wt.	1	2	Criteria	Definition
Weight	0.10	**3**	**4**	**Weight**	**Overall weight that the motor adds to the plane**
Thrust	0.30	**3**	**5**	**Thrust**	**The amount of reaction force that the motor can create using the propeller**
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.

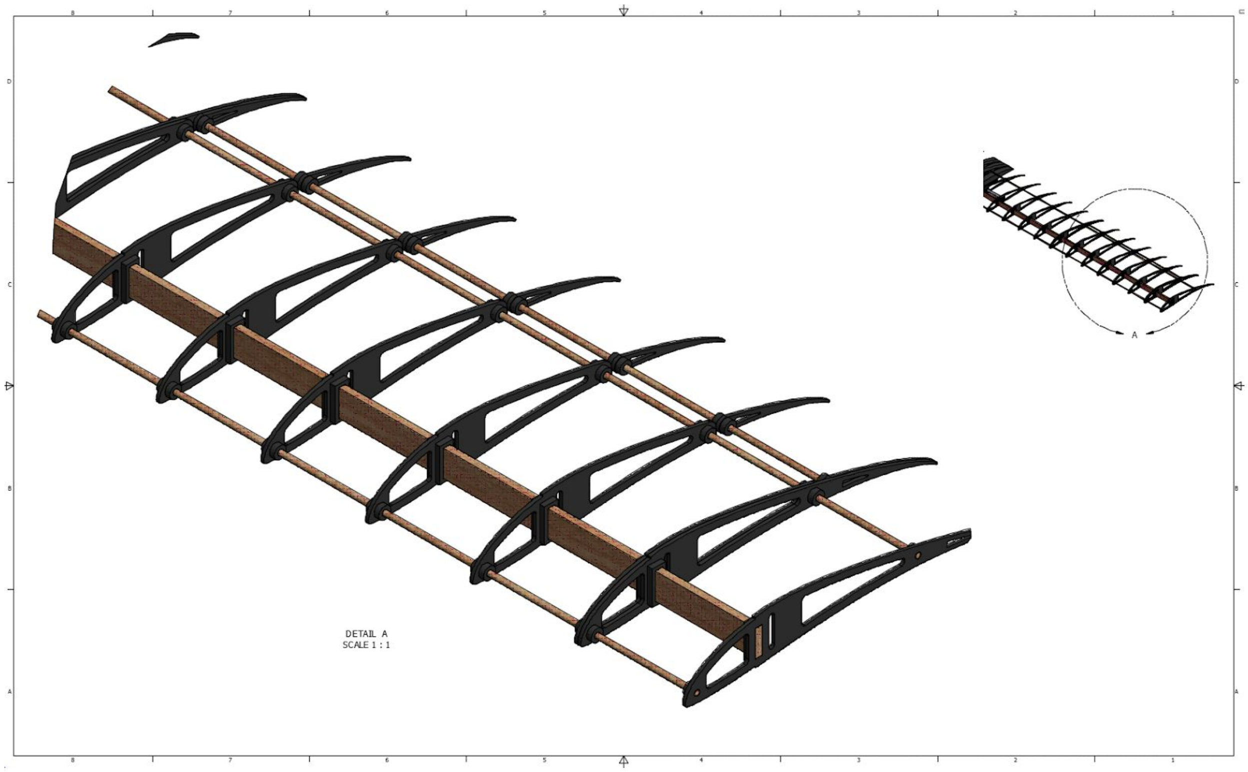
8) Wing Design



Above is the finalized wing design. It consists of 3D printed support structure, balsa wood laser cut ribs, balsa wood spars, a 30” aluminum spar, and a pine wood main spar.

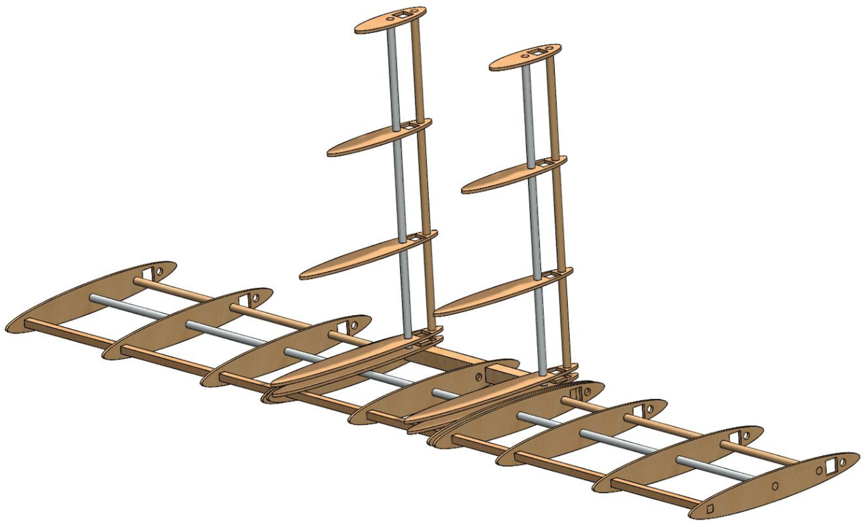


Above is the detailed view of the center of the wing. It shows the complex structure and how the two halves of the wing are connected securely.

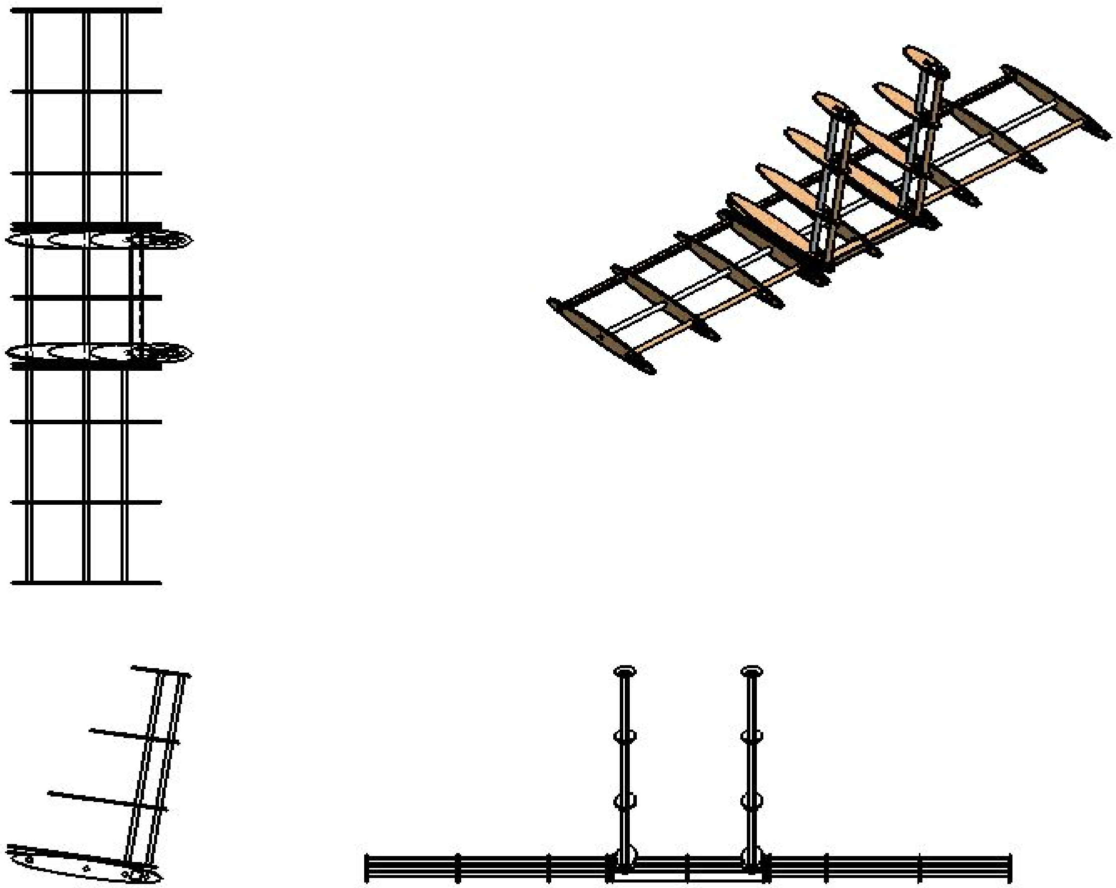


Above is a detailed view of the aileron of the wing design. The aileron is fully integrated into the design to provide structural integrity and allow for great mobility.

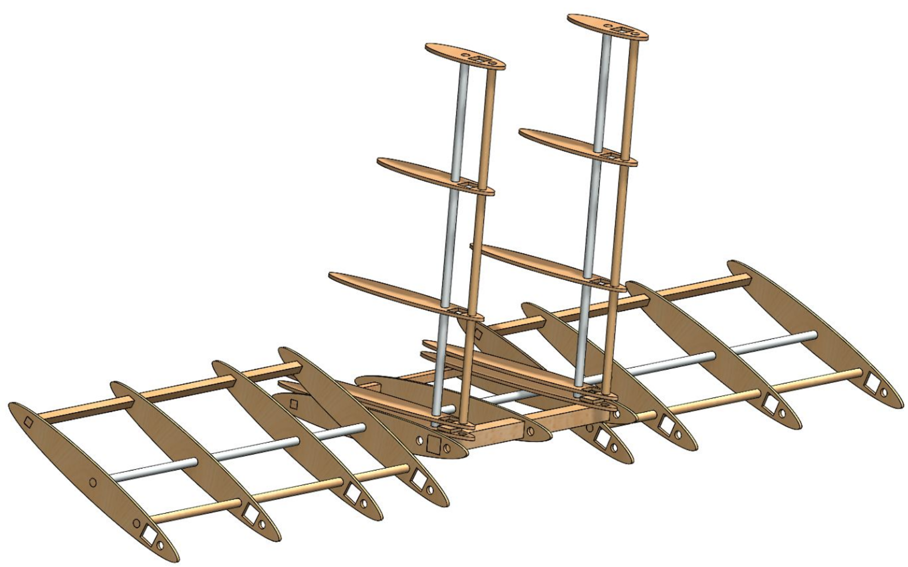
9) Tail Design



Above is the tail design for our airplane on solid works. This twin tail design will be attached by super gluing the wooden parts, while attaching the aluminum pipe by washers in each side and put a screw through it.



The figure above shows the front, top, and right view for our tail design.



The figure above shows that each part of the vertical and horizontal stabilizer moves each way, up, and down, and right and left.

10) Final Components

- Motor - AXI 5325/16 GOLD LINE

- Propeller - APC 18x12WE

- ESC/BEC-CASTLE CREATIONS Phoenix Edge 75

- Battery-Eflight 3200mAh 6S 22.2V 30C LiPo, 12AWG EC3

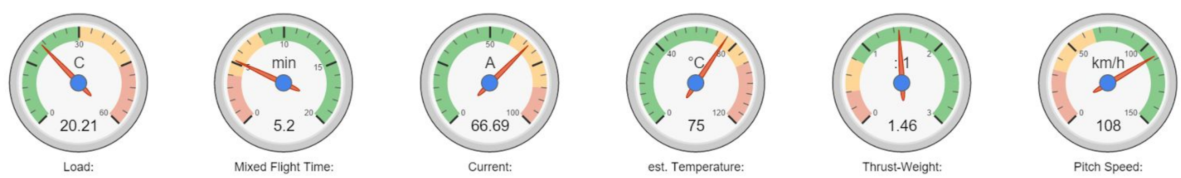
- Receiver-AR610 6-Channel DSMX Aircraft Receiver (SPMAR610)

- Servos-Extra High Torque Servo (SPMS601H)

11) Flight Calculations

General	Motor Cooling: medium	# of Motors: 1 (on same Battery)	Model Weight: 4536 g / 160 oz, incl. Drive		Wing Area: 96.8 dm² / 1500 in²	Field Elevation: 500 m ASL / 1640 ft ASL	Air Temperature: 25 °C / 77 °F	Pressure (QNH): 1013 hPa / 29.91 inHg
Battery Cell	Type (Cont. / max. C) - charge state: LiPo 3300mAh - 30/45C - normal	Configuration: 6 S 1 P	Cell Capacity: 3300 mAh	Total Capacity: 3300 mAh	Resistance: 0.0052 Ohm	Voltage: 3.7 V	C-Rate: 30 C cont. / 45 C max	Weight: 93 g / 3.3 oz
Controller	Type: CC Phoenix Edge 75	cont. Current: 75 A	max. Current: 75 A		Resistance: 0.010 Ohm			Weight: 114 g / 4 oz
Motor	Manufacturer - Type (Kv): AXI 5325/16 (350) search...	KV (w/o torque): 350 rpm/V	no-load Current: 2.1 A @ 30 V	Limit (up to 15s): 85 A	Resistance: 0.026 Ohm	Case Length: 59 mm / 2.32 inch	# mag. Poles: 14	Weight: 575 g / 20.3 oz
Propeller	Type - yoke twist: APC Electric E - 0°	Diameter: 18 inch	Pitch: 12 inch	# Blades: 2	PConst / TConst: 1.08 / 1.0	Gear Ratio: 1 : 1	Flight Speed: 32.2 km/h / 20 mph	calculate

Above is the inputted information into the online calculator that solves for the performance of the aircraft with the selected final components.



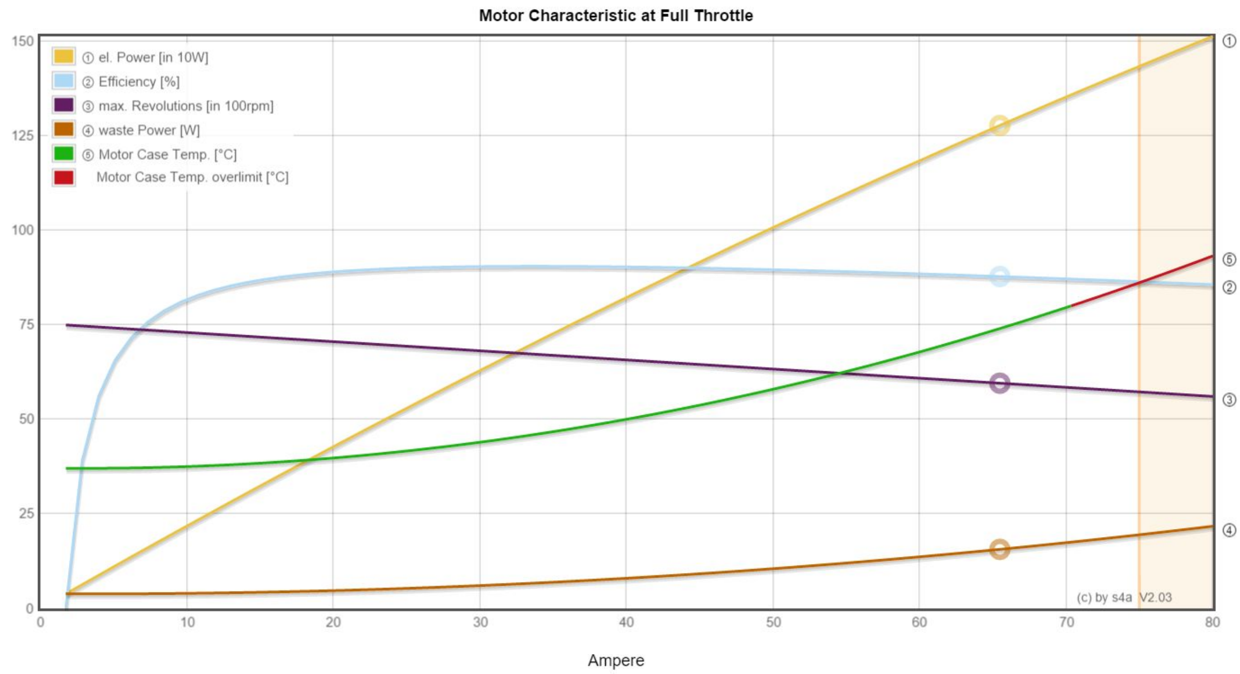
Remarks:

Battery		**Motor @ Optimum Efficiency**		**Motor @ Maximum**		**Propeller**		**Total Drive**		**Airplane**	
Load:	20.21 C	Current:	33.62 A	Current:	66.69 A	Static Thrust:	6615 g	Drive Weight:	1372 g	All-up Weight:	4536 g
Voltage:	20.12 V	Voltage:	20.81 V	Voltage:	19.45 V		233.3 oz		48.4 oz		160 oz
Rated Voltage:	22.20 V	Revolutions*:	6725 rpm	Revolutions*:	5927 rpm	Revolutions*:	5927 rpm	Power-Weight:	326 W/kg	Wing Load:	47 g/dm²
Capacity:	3300 mAh	electric Power:	699.8 W	electric Power:	1297.3 W	Stall Thrust:	3844 g		148 W/lb		15.4 oz/ft²
Energy:	73.26 Wh	mech. Power:	633.1 W	mech. Power:	1136.6 W		135.6 oz	Thrust-Weight:	1.46 : 1	Cubic Wing Load:	4.8
Flight Time:	3.0 min	Efficiency:	90.5 %	Efficiency:	87.6 %	Thrust @ 32.2 km/h:	4650 g	P(in) @ max:	1480.5 W	est. Stall Speed:	33 km/h
Mixed Flight Time:	5.2 min			est. Temperature:	75 °C	Thrust @ 20 mph:	164 oz	P(out) @ max:	1136.6 W		20 mph
Weight:	558 g				167 °F	Pitch Speed:	108 km/h	Efficiency @ max:	76.8 %	est. Speed (level):	97 km/h
	19.7 oz						67 mph				60 mph
						Tip Speed:	511 km/h			est. Speed (vertical):	33 km/h
							317 mph				20 mph
						specific Thrust:	2.96 g/W			est. rate of climb:	10.1 m/s
							0.1 oz/W				1982 ft/min

Motor Partial Load

Propeller rpm	Throttle %	Current (DC) A	Volage (DC) V	el. Power W	Efficiency %	Thrust g	Spec. Thrust g/W	Pitch Speed km/h	Thrust oz	Spec. Thrust oz/W	Pitch Speed mph	Flight Time (85%) min
800	11	0.3	22.2	6.2	45.3	121	19.6	15	4.3	0.69	9	599.9
1200	17	0.7	22.2	14.8	63.9	271	18.4	22	9.6	0.65	14	250.2
1600	22	1.4	22.2	30.0	74.5	482	16.1	29	17.0	0.57	18	122.9
2000	28	2.5	22.1	54.1	80.6	753	13.9	37	26.6	0.49	23	67.8
2400	34	4.1	22.1	89.6	84.1	1085	12.1	44	38.3	0.43	27	40.8
2800	40	6.4	22.0	138.9	86.2	1476	10.6	51	52.1	0.37	32	26.2
3200	47	9.5	21.9	204.5	87.4	1928	9.4	59	68.0	0.33	36	17.7
3600	53	13.6	21.8	288.9	88.1	2440	8.4	66	86.1	0.30	41	12.4
4000	60	18.7	21.6	394.9	88.4	3013	7.6	73	106.3	0.27	45	9.0
4400	**67**	**25.2**	**21.4**	**525.1**	**88.5**	**3646**	**6.9**	**81**	**128.6**	**0.24**	**50**	**6.7**
4800	75	33.2	21.2	682.3	88.4	4339	6.4	88	153.0	0.22	55	5.1
5200	83	42.9	20.9	869.2	88.2	5092	5.9	95	179.6	0.21	59	3.9
5600	92	54.9	20.5	1088.9	88.0	5905	5.4	102	208.3	0.19	64	3.1
5927	100	66.7	20.1	1297.3	87.6	6615	5.1	108	233.3	0.18	67	2.5

Above is the results that was given from the online calculator that shows how the aircraft will perform at the competition. It uses the elevation of the airfield and the weight and power from each component to solve for the performance.



A graph of the results are given graphically above.

12) Bill of Materials

Table 17. Bill of Materials

Items	Quantity	Description	Cost	Website
Motor	1	AXI 5325/16 GOLD LINE	$ 299.99	http://www.hobbyexpress.com/axi_gold_5325_16_outrunner_motor_522473_prd1.htm
Motor mount	1	N/A		
Propeller	1	APC 18x12WE	$ 11.72	http://www.apcprop.com/product_p/lp18012we.htm
Nose gear	1	Nose Gear with Nose Gear Mount Block (HAN1306)	$ 4.99	http://www.horizonhobby.com/nose-gear-with-nose-gear-mount-block-han1306
Landing gear	1	Constructing at machine shop		
ESC/BEC	1	CASTLE CREATIONS Phoenix Edge 75	$ 101.96	http://www.castlecreations.com/products/phoenix-edge.html
Battery	1	Eflight 3200mAh 6S 22.2V 30C LiPo, 12AWG EC3	$ 99.99	http://www.horizonhobby.com/helicopters/batteries/3200mah-6s-222v-30c-lipo--12awg-ec3-eflb32006s30
Arming plug	1	SAE 2016 Arming Safety Harness	$ 30.00	http://neumotors.cartloom.com/shop/item/111799
Power limiter	1	SAE Limiter V2 2016	$ 50.00	http://neumotors.cartloom.com/shop/item/24377
Receiver	1	AR610 6-Channel DSMX Aircraft Receiver (SPMAR610)	$ 49.99	http://www.horizonhobby.com/ar610-6-channel-dsmx-aircraft-receiver-spmar610
Servos	5	Extra High Torque Servo (SPMS601H)	$ 44.99	http://www.horizonhobby.com/extra-high-torque-hybrid-servo-spms601h
Y-harness	2	Y-Harness: Telemetry (SPM1516)	$ 5.99	http://www.horizonhobby.com/y-harness%3A-telemetry-spm1516
Wheels (2 orders)	4	Big Wheels, 4" (DUB400RV)	$ 15.49	http://www.horizonhobby.com/big-wheels--4-dub400rv
Balsa dowels	10	3/16" x 3' balsa dowels	$57.80	http://www.specializedbalsa.com/cart.php
Balsa sheeting	6	Balsa Sheet 3/16 x 12 x 36	$112.59	http://www.specializedbalsa.com/cart.php
Pine spar	2	2in.x4in.x10ft Kiln-Dried Heat Treated Spruce-Pine-Fir Lumber (161659)	$ 4.05	http://www.homedepot.com/p/Unbranded-2-in-x-4-in-x-10-ft-Standard-Better-Kiln-Dried-Heat-Treated-Spruce-Pine-Fir-Lumber-161659/100077951
Aluminum tubing	1	36 in. x 1/2 in. x 1/16 in. Aluminum Round Tube	$ 10.67	http://www.homedepot.com/p/Crown-Bolt-36-in-x-1-2-in-x-1-16-in-Aluminum-Round-Tube-35190/202183508
Aluminum sheeting	n/a	3/16" Aluminum Scraps	Donated	
1/32-in nylon-coated cable	1	Loos Galvanized Steel Wire Rope, Nylon Coated, 7x7 Strand Core	$ 12.16	http://www.amazon.com/Loos-Galvanized-Coated-Breaking-Strength/dp/B0050K3476/ref=sr_1_1?s=industrial&ie=UTF8&qid=1449792941&sr=1-1&keywords=1%2F32+nylon+coated+cable
ABS	29.58in^3	$250/52in^3	$ 142.22	
TOTAL			**$ 1,054.6**	

Table 17 above shows the bill of materials for the team's aircraft. The motor, battery, ESC/BEC (Electronic Speed Control/Battery Eliminator Circuit), balsa, and ABS plastic take up the bulk of the airplane costs. The receiver and servos also add a significant amount of cost. Funds will be received from NAU SAE, specifically for the ABS. The ABS three-dimensional print is needed for the center of our wing because it must be one solid piece to have the amount of strength that needed to support the weight of the aircraft. The landing gear, motor mount, and aluminum sheeting will all be machined. The arming plug and power limiter are specified SAE competition requirements.

13) Project Plan

Table 18: 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															◆

14) Conclusion

In conclusion, the Northern Arizona University SAE Aero senior capstone team will design and build an aircraft to compete, as representatives of Northern Arizona University, in the SAE Aero design competition. The capstone team has begun to design and build an aircraft that adheres to the SAE Aero competition requirements and constraints. A wing design has been finalized and will begin construction shortly. A tail design has been presented and the design will be finalized soon. Final components of the aircraft, such as the motor and propeller that the team will purchase have been chosen. A rough estimate of the cost of constructing the aircraft has been proposed with a bill of materials. The team will finish design and construction next semester, as well as compile a report detailing the final design and manufacturing processes that the team will also orally present.

15) 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].

[6] Flight calculations. Ecalc Calc for Airplanes. [Online]. Available at: http://www.ecalc.ch/