SAE AERO: Micro Class

Spencer Makar – Project Manager

Ethan Shoemaker – Logistics Manager

Ryan Downey – Test Engineer

Conner Nolan – Manufacturing Engineer

Katrina Kevorkian – Financial Manager

Hector Medrano – CAD Engineer

Project Description

- SAE Micro Aero Competition
  - Build and design full electric airplane to compete in S22
  - Abide by standards and rules outlined in competition handbook
  - Stakeholders: Dr. Willy, CEIAS
- Objectives
  - Prototype and test airplane soon and often
  - Refine and improve areas of weakness

Black-Box Model

Figure 1: Black-box Model

Functional Decomposition

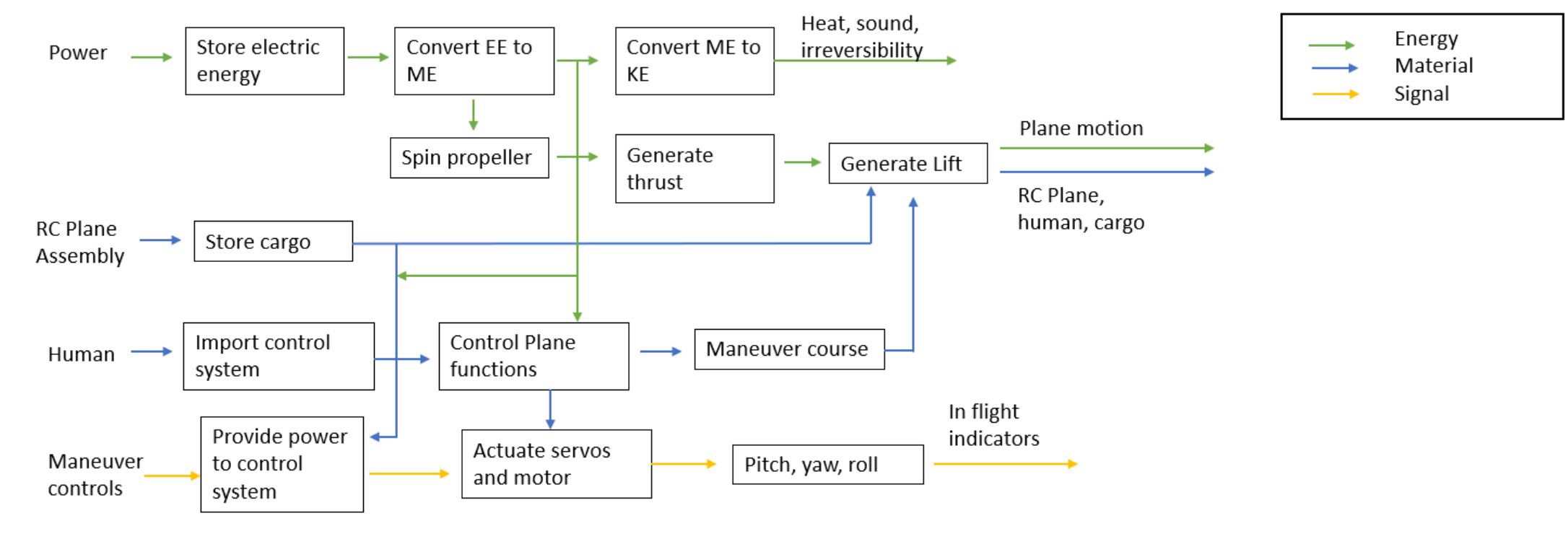


Figure 2: Functional Decomposition

Concept Generation

- Concepts needed:
  - Wings, Propeller, Tail, Fuselage, Powerplant, and Landing Gear
- C-Sketch
  - Each team member created and annotated their own concepts [1].

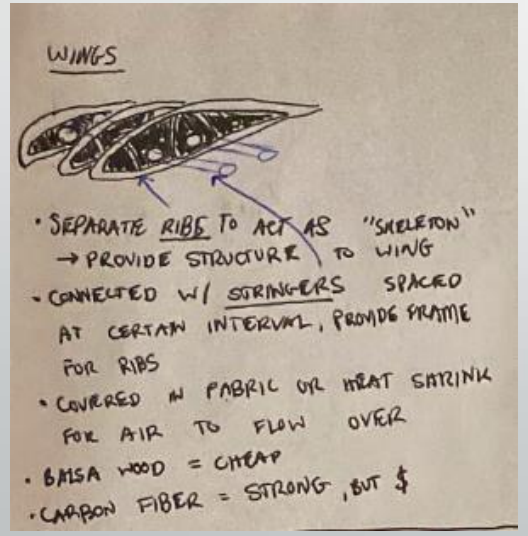


Figure 3: Rib Style Wings

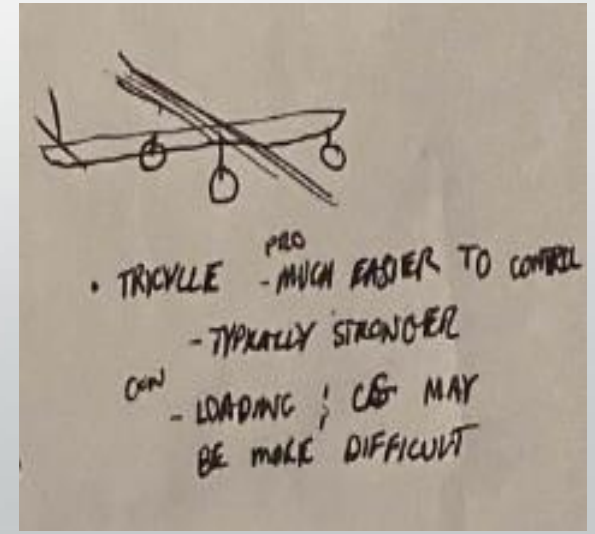


Figure 4: Tricycle Landing Gear

Concept Generation (cont.)

Rib and Spar Airfoil

- Advantages
  - Wiring harness/servo motor housed inside of wing
- Disadvantages
  - More labor intensive
  - More precise measurements

Tricycle Landing Gear

- Advantages
  - Allows tail ample ground clearance on take-off to achieve higher AoA to generate lift for T/O
  - Ground stability increased
- Disadvantages
  - Aft CG with payload, aircraft will tip onto tail
  - Less variability with payload placement in relation to CG

Morph Matrix

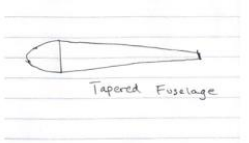
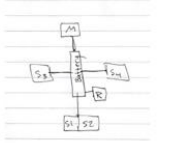
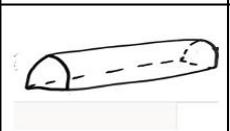
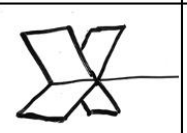
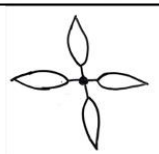
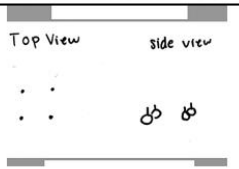
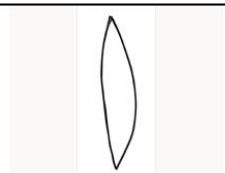
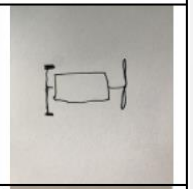
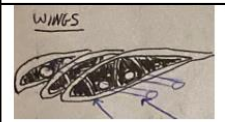
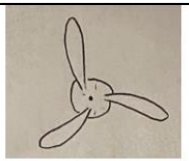
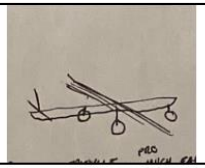
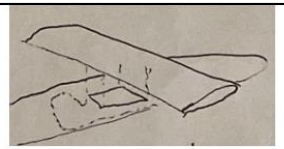
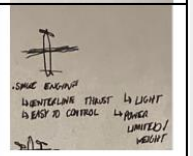
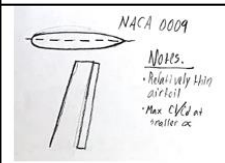
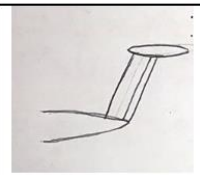
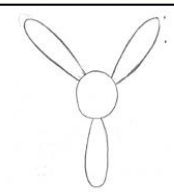
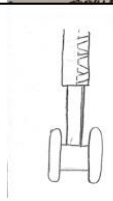
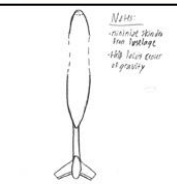
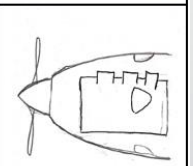
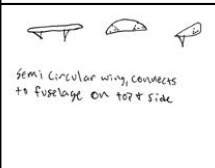
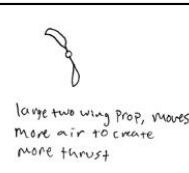
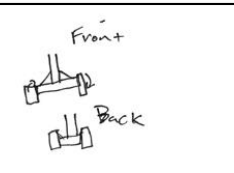
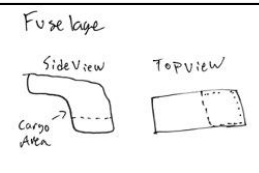
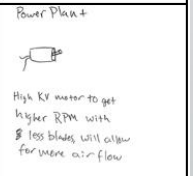
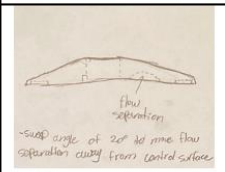
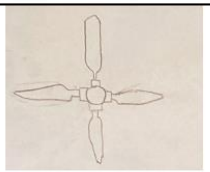
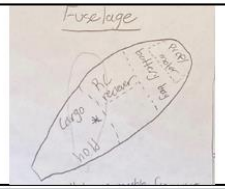
	Wings	Tail	Propeller	Landing Gear	Fuselage	Powerplant
Ethan						
Katrina						
Spencer						
Hector						
Ryan						
Conner						

Figure 5: Morph Matrix

Concept Evaluation Pugh Chart

Table 1: Designs

	Design 1	Design 2	Design 3	Design 4
Airfoil	NACA 4412	Selig 3002	NACA 2412	NACA 6412
Fuselage	Tapered	Large Box	Large Box	Tapered
Tail	Conventional	Conventional	Conventional	Conventional
Material	Balsa Wood	Carbon Fiber	Foam	Balsa Wood
Powerplant	4S Battery (14.8 V)	3S Battery (11.1 V)	3S Battery (11.1 V)	4S Battery (14.8 V)
Battery Capacity	1200 mAh	2200 mAh	3600 mAh	1000 mAh
Landing Gear	Taildragger	Tricycle	Tricycle	Tricycle

Table 2: Pugh Chart

Pugh Chart					
Engineering Characteristics	**Weights**	**Design 1**	**Design 2**	**Design 3**	**Design 4**
Battery Capacity	2	DATUM	+	+	+
Flight Control	7		S	S	+
Ground Control	5		-	-	S
Lift	10		-	-	+
Drag	7		-	-	-
Weight	6		+	+	+
Thrust/Motor	8		-	-	S
Cost	3		-	+	-
Durability	5		+	-	S
Cargo Volume	7.5		+	+	S
Total +		0	4	4	4
Total -		0	5	5	2
Overall Weighted Score		0	-12.5	-16.5	15

Concept Evaluation: Airfoil Comparison

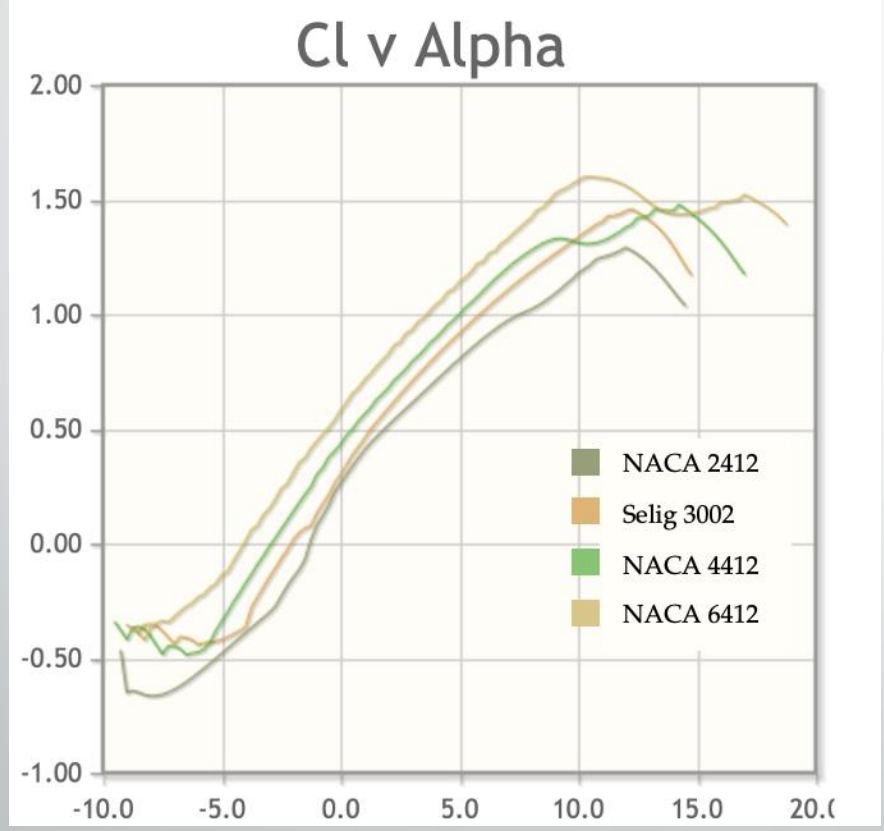


Figure 6: Cl Analysis of 4 Airfoils at Re 100,000

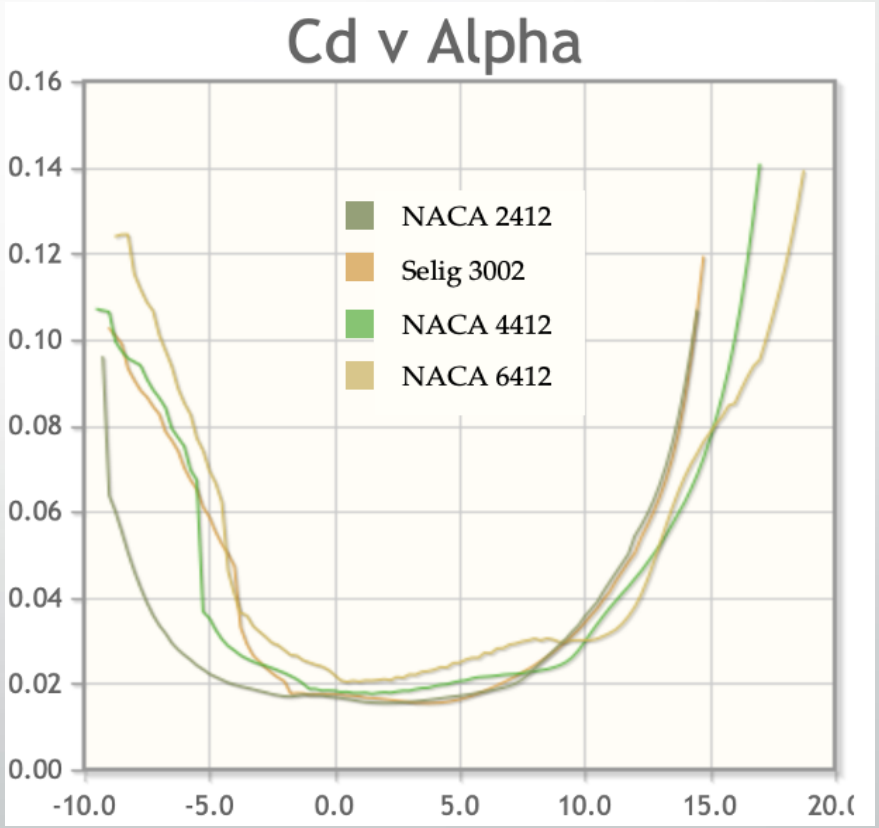


Figure 7: Cd Analysis of 4 Airfoils at Re 100,000

Concept Evaluation: Decision Matrix

Table 3: Decision Matrix

		Design 1		Design 4	
Criteria	Weights (%)	Score	Weighted Score	Score	Weighted Score
Lift/Drag	30	3.5	1.05	4.5	1.35
Thrust	20	4	0.8	4	0.8
Weight	15	3.5	0.525	4	0.6
Control	15	4	0.6	4.5	0.675
Power	10	3.5	0.35	4	0.4
Cost	10	4	0.4	3.5	0.35
Total	100		3.725		4.175

Design Analysis

- Design analysis process is broken into two parts
  - Lift must be greater than the weight of the aircraft, so an estimate must be made
  - In order to make a weight estimate, an electronic system must be chosen

Lift Analysis

- Lift must be greater than weight
  - $C_L \frac{1}{2} \rho V^2 A > W$
  - Velocity is unknown and dependent on thrust produced
  - Research of motors shows we can expect about 18 N of thrust
- Rough propeller analysis
  - Applying Bernoulli's equation across propeller yields V = 26.76 m/s (59.86 mph)
  - This is a bad estimate because it does not account for drag or wheel friction when the plane is on the ground
  - Assume V_p = 0.8V = 21.4 m/s at takeoff
- Plugging in V and W to above equation:
  - Dry Weight required coefficient of lift: 0.26
  - With payload: 0.38

Electronics Analysis

- All electronic components must be chosen and have their current draw analyzed
- Following this, a battery of sufficient capacity must be chosen

Table 4: Power Analysis

Component	Current Draw (mA)
Servos (x5)	3000
Receiver	30
Motor	30400
Total	**33430**

- Building in a slight factor of safety, assume total draw of 35000 mA
- A 1000 mAh battery will support this system for almost 2 minutes

Weight Analysis

Table 5: Weight Estimation

Part	Weight (g)
Motor	130
Battery	125
Servos (x5)	49
Receiver	9
Propeller	15
Wings	35
Fuselage	175
ESC	45
SAE Package 1	85
SAE Package 2	170
Dry Weight	**583**
Weight with Payload	**838**

Lift Analysis (cont.)

- Must ensure operation between Re 100,000-500,000
- Need Coefficient of lift of at least 0.38

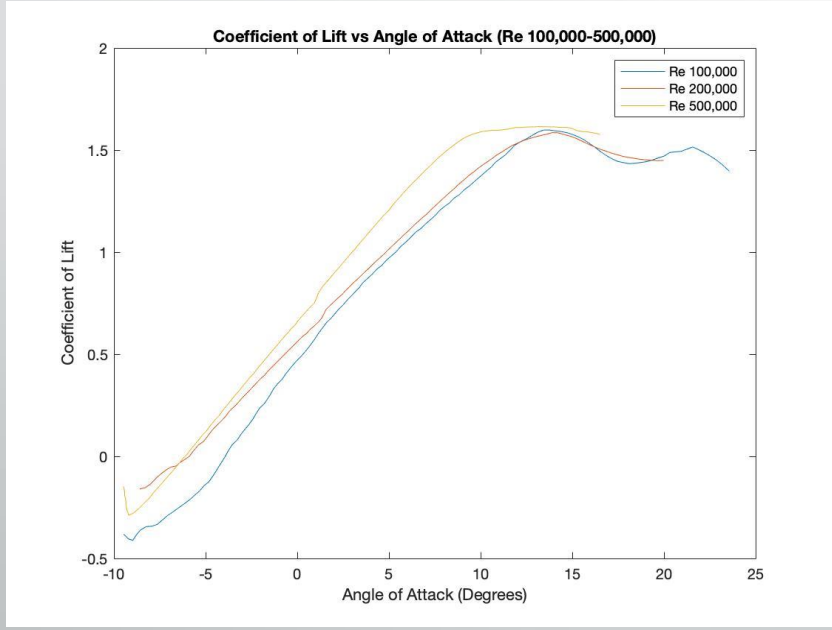


Figure 8: NACA 6412 Lift Data

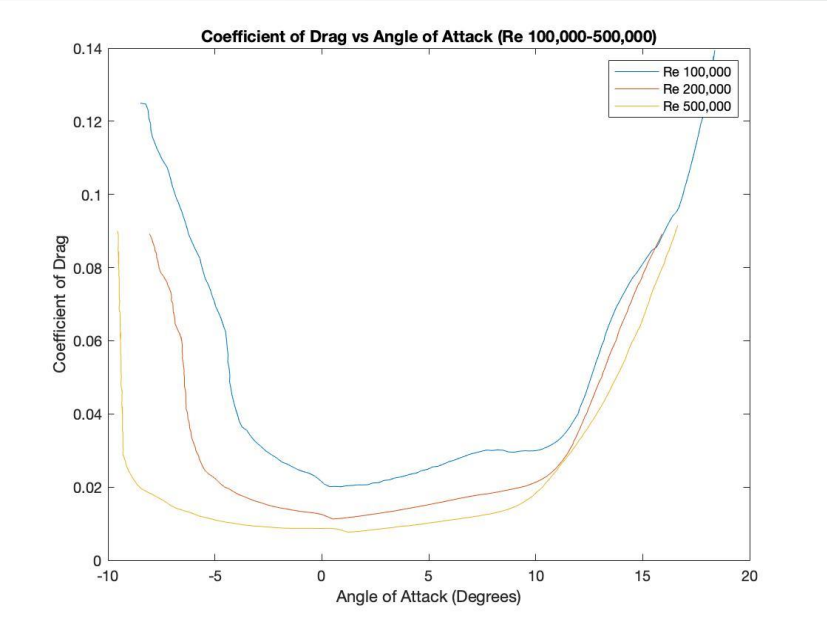


Figure 9: NACA 6412 Drag Data

CAD Model/First Iteration

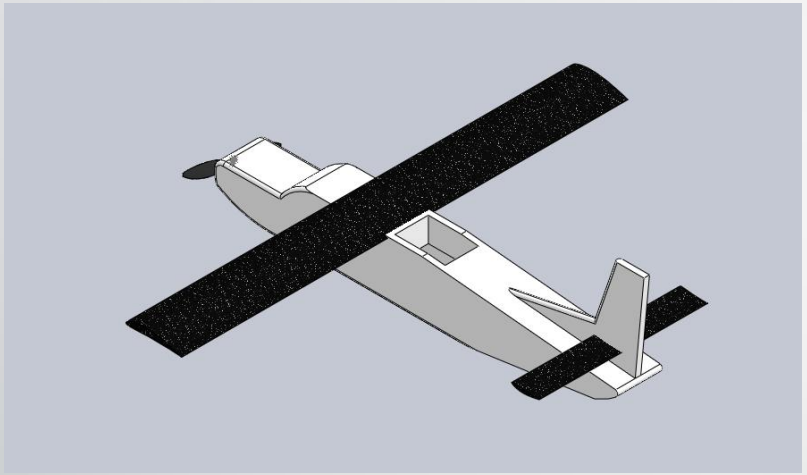


Figure 10: Rear Isometric

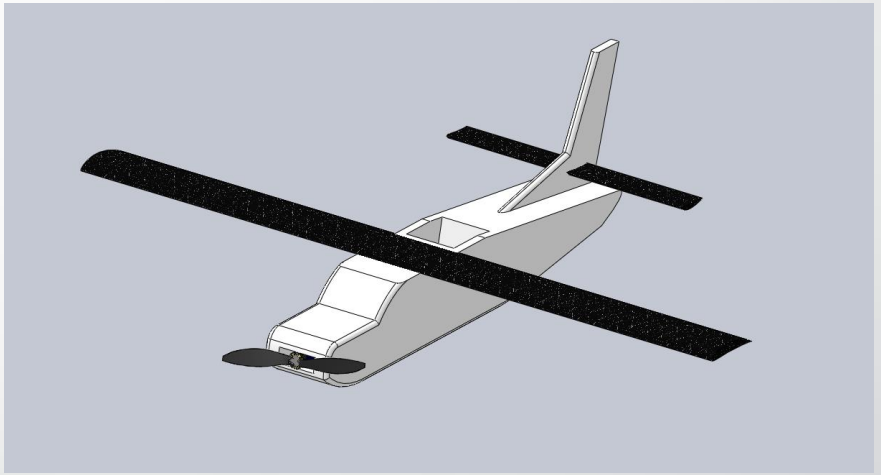


Figure 11: Isometric

Figure 12: Side View

Bill of Materials

Table 6: Bill of Material

Bill Of Materials					
Item Number	Item Name	Where to Purchase	Quantity	Cost Approximation	Notes
1	Transmitter	https://scale-model-aircraft.com/reviews/best-rc-transmitter-for-planes	1	$-	Used last years
2	Servos	https://hobbyking.com/en_us/hxt900-micro-servo-1-6kg-0-12sec-9-8g.html?queryID=ddf03f31299b33ef2bacabd17d1ee992&objectID=29623&indexName=hbk_live_products_analytics#qa[bW9kZT03JnBhZ2U9MSZxdWVzdGlvbl9zZWFyY2hfY29udGVudDo=]	10	$40.00	
3	Power Limiter	https://neumotors.cartloom.com/storefront/product/sae-2021-limiters	1	$75.00	
4	Receivers		1	$-	Used last years
5	Motor	https://www.scorpionsystem.com/catalog/aeroplane/motors_1/s-30_v2/SII-3014-1040KV/	1	$100.00	
6	Propellers	https://www.apcprop.com/product/9x4-5e/	10	$30.00	
7	Speed Controller	https://hobbyking.com/en_us/turnigy-plush-32-40a-2-6s-brushless-speed-controller-w-bec-rev1-1-0.html	1	$22.00	
8	Battery	https://hobbyking.com/en_us/turnigy-nano-tech-1000mah-4s-70c-lipo-pack-xt60-hr-tech.html?queryID=8576f186bcf6b0a6ff30460e8cc1cd94&objectID=76048&indexName=hbk_live_products_analytics	4	$72.00	
9	Balsa Wood	https://www.hobbylobby.com/Crafts-Hobbies/Hobbies-Collecting/Balsa-Hobby-Wood/Balsa-Wood-Sheet---1-8%22-x-3%22-x-36%22/p/72021	5	$20.00	Used for wings
10	Body Material	https://www.michaels.com/elmers-foam-board-white/10110205.html	4	$12.00	Used last years
11	Kill Switch		1	$-	Used last years
12	Landing Gear		1	$-	Used last years
13	Wing Material	https://www.horizonhobby.com/product/econokote-black-6/TOPQ2608.html	1	$13.00	
-	-	-	-	**$384**	

Budget

Table 7: Budget

SAEaero Capstone Project

NOTE: Difference columns in table will show if actual went over estimated amounts. Red numbers show went over (negative) and black shows under numbers (positive).

			Itemized Cost ($)			Total Cost ($)		
Area	Items	Quantity	Estimated	Actual	Difference	Estimated	Actual	Difference
Electronics	Servos	10	($4.00)			($40.00)		
Electronics	Power Limiter	1	($75.00)			($75.00)		
Electronics	Speed Controller	1	($22.00)			($22.00)		
Electronics	Battery	4	($18.00)			($72.00)		
Fuselage	Material for Body	4	($3.00)			($12.00)		
Motor	Motor	1	($100.00)			($100.00)		
Propeller	9x4 Propeller	10	($3.00)			($30.00)		
Registration Fee	Registration Fee	1	($1,500.00)			($1,500.00)		
Total Budget	Total Budget	1	$3,000.00			$3,000.00		
Wings	Balsa Wood	5	($4.00)			($20.00)		
Wings	Material for Wings	1	($13.00)			($13.00)		
Subtotal			**$1,258.00**	**$0.00**	**$0.00**	**$1,116.00**	**$0.00**	**$0.00**
Unexpected Costs (add 5% estimated)			**($62.90)**			**($55.80)**		
Total costs			**$1,195.10**			**$1,060.20**		

References

[1] Oman, Sarah, "Hypothesized Functional Modeling,: *Northern Arizona University*, 2016[Online] Available: https://learn-us-east-1-prod-fleet02-xythos.content.blackboardcdn.com/5b6cbef360ea4/8696201?X-Blackboard-Expiration=1633413600000&X-Blackboard-Signature=DBkNmEB5vjgNpZbW3FnOdGLvzY8PMh8%2Fi68tYGrGNOo%3D&X-Blackboard-Client-Id=200134&response-cache-control=private%2C%20max-age%3D21600&response-content-disposition=inline%3B%20filename%2A%3DUTF-8%27%27Hypothesized%2520Functional%2520Models.pdf&response-content-type=application%2Fpdf&X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Date=20211005T000000Z&X-Amz-SignedHeaders=host&X-Amz-Expires=21600&X-Amz-Credential=AKIAZH6WM4PL5SJBSTP6%2F20211005%2Fus-east-1%2Fs3%2Faws4_request&X-Amz-Signature=83f0e3236f58c24b2dd57755a79c6f21dd9f8470bd9b19c4e463c865c044acd5 [Accessed 01-Oct-2021]

[2] "Propeller thrust," *NASA*. [Online]. Available: https://www.grc.nasa.gov/www/k-12/airplane/propth.html. [Accessed: 04-Oct-2021].

[3] "Scorpion sii-3014-1040KV (V2)," *Scorpion SII-3014-1040KV (V2) - Scorpion Power System*. [Online]. Available: https://www.scorpionsystem.com/catalog/aeroplane/motors_1/s-30_v2/SII-3014-1040KV/. [Accessed: 04-Oct-2021].

[4] "Airfoil Tools," *Airfoil Tools*. [Online] Available: http://airfoiltools.com/airfoil/details?airfoil=naca6412-il [Accessed: 01-Oct-2021].

[5] "Free CAD designs, Files & 3D models: The grabcad community library," *Free CAD Designs, Files & 3D Models | The GrabCAD Community Library*. [Online]. Available: https://grabcad.com/library/9x4-7-propeller. [Accessed: 03-Oct-2021].

[6] "Free CAD designs, Files & 3D models: The grabcad community library," *Free CAD Designs, Files & 3D Models | The GrabCAD Community Library*. [Online]. Available: https://grabcad.com/library/scorpion-motors-sii-4025-330kv-1. [Accessed: 03-Oct-2021].