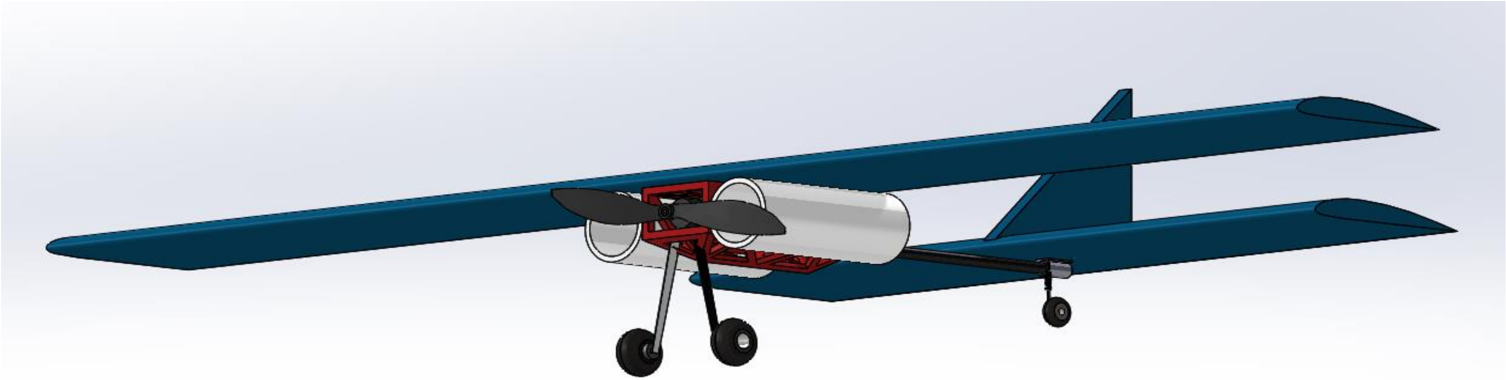
SAE Aero Micro Presentation 3:

Final Design Proposal



NAU Capstone 2019-2020: The Prop Dogs
Corbin Miller, Eli Perleberg, and Zach Simmons
11/5/19

Eli

Agenda

1. **Project review and description**
2. **Design description, CAD model, and prototype**
3. **Subsystem-level designs**
    a. Drive
    b. Fuselage
    c. Wing
    d. Landing gear
    e. In-flight control
4. **Design requirement satisfaction**
5. **Design validation and future testing**
6. **Updated BOM and schedule**

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Project Review & Description

SAE Aero Micro Class Design: April 3-5, 2020 in Fort Worth, TX

Design process to date:

- Literature Review
- State of the Art Design
- CRs, ERs, and QFD
- Initial Budget and Schedule
- Functional Decomposition: Black Box and Functional Model
- Concept Generation: Methodology and Subsystems
- Subsystem Variants
- Designs Considered
- Concept Evaluation: Pugh Chart & Decision Matrix
- Concept Selection
- Budget Planning

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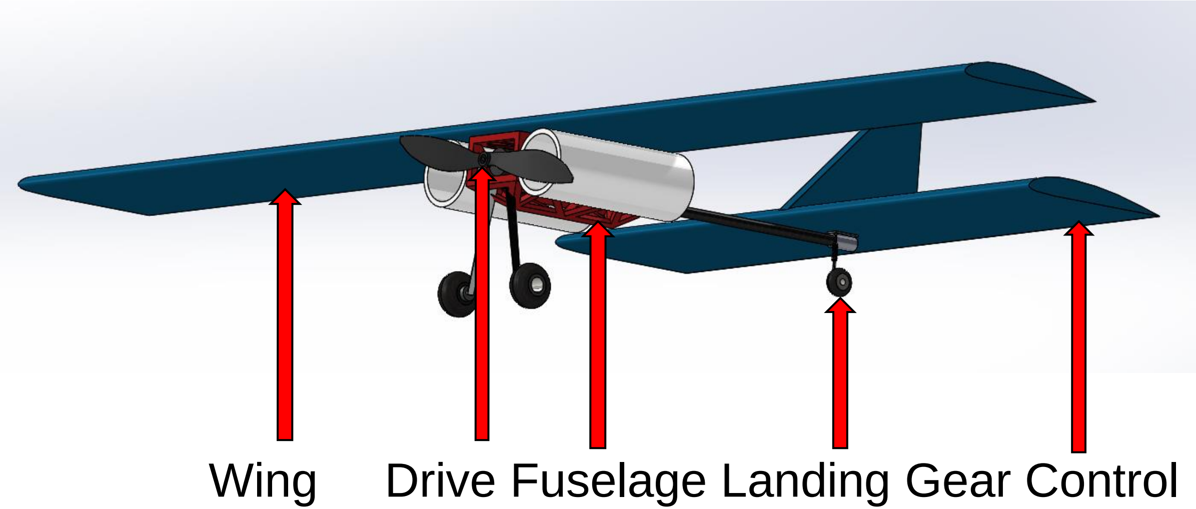
Design Description: Current State Model



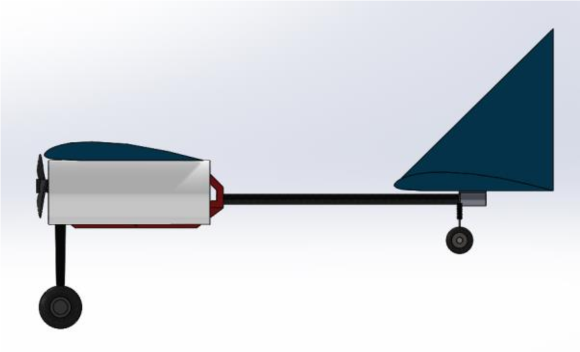


Figure 2: Current State CAD (Front View)

Figure 1: Current State CAD (ISO View)

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Design Description: Current State Model

Table 1: Current State Model

Subdesign	Implementation Details
Drive	Propeller, motor, ESC, battery, wiring
Fuselage	Frame geometry and material, drive housing, carbon fiber rod, PVC payload
Wing	Airfoil selection, chord length, wingspan, aspect ratio, material
Landing Gear	Geometry, material
In-Flight Control	Linkages, motors, receiver, controller

Zach

Drive Design

Propeller→ Motor→ Electronic Speed Controller (ESC)→ Battery

$$1\ glow\ equiv. = 2000W$$

$$\sim \frac{100W}{lb}\ needed\ to\ fly$$

$$Assume\ All\ Up\ Weight = 4\ lb$$

$$400W\ needed = 0.2\ glow\ equiv.$$

Given prop chart→ 8x4 or 8x6 prop
Selected propeller: APC Electric 8x4.7 SF

Figure 4: APC Electric 8x4.7 SF

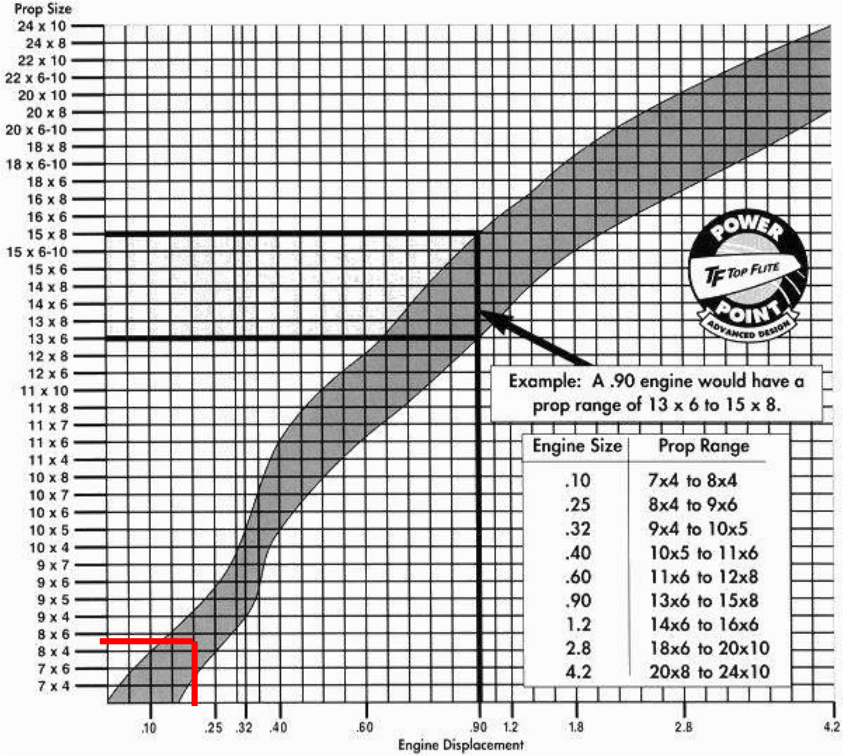

Figure 3: Propeller Chart

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Drive Design

Propeller→ **Motor**→ Electronic Speed Controller (ESC)→ Battery

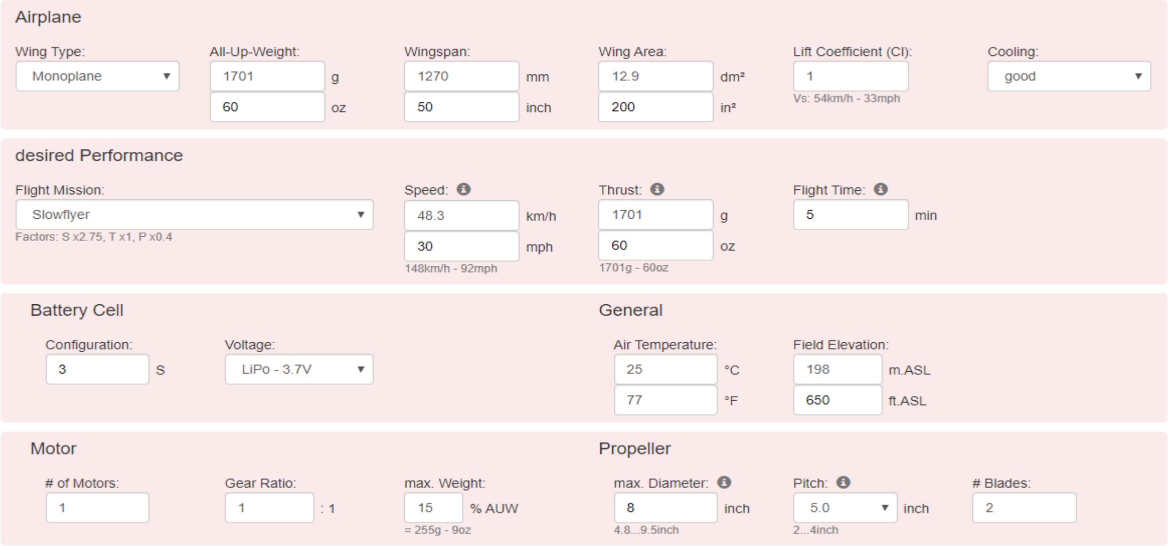

Table 2: Motor Selection

Propeller	Motor	KV	ESC	Battery	Current	Speed		Thrust	
inch		rpm/V	A+		A	km/h	mph	g	oz
8x5.0	NeuMotors 1509/3.75D TL4	1760	55	2600mAh - 20C (3s1p)	41	118	73	1649	58.2
8x5.0	Scorpion HK-2520-1880	1880	60	2800mAh - 20C (3s1p)	44	117	73	1632	57.6
8x4.7	Mega Motor ACn 22/30/2	1920	65	3000mAh - 20C (3s1p)	49	117	73	1733	61.1
8x4.75	Mega Motor ACn 22/30/2	1920	65	3000mAh - 20C (3s1p)	49	118	73	1745	61.6
8x5.25	Leomotion L3025-1800-V2	1820	55	2600mAh - 20C (3s1p)	40	118	73	1593	56.2

Begin with trusted manufacturer: Scorpion Power System

Selected Motor:
Scorpion HK-2520-1880

- High Energy-to-weight ratio
- Brushless motor
- 800W max power
- Scorpion ESC compatible

Figure 5: Scorpion Motor

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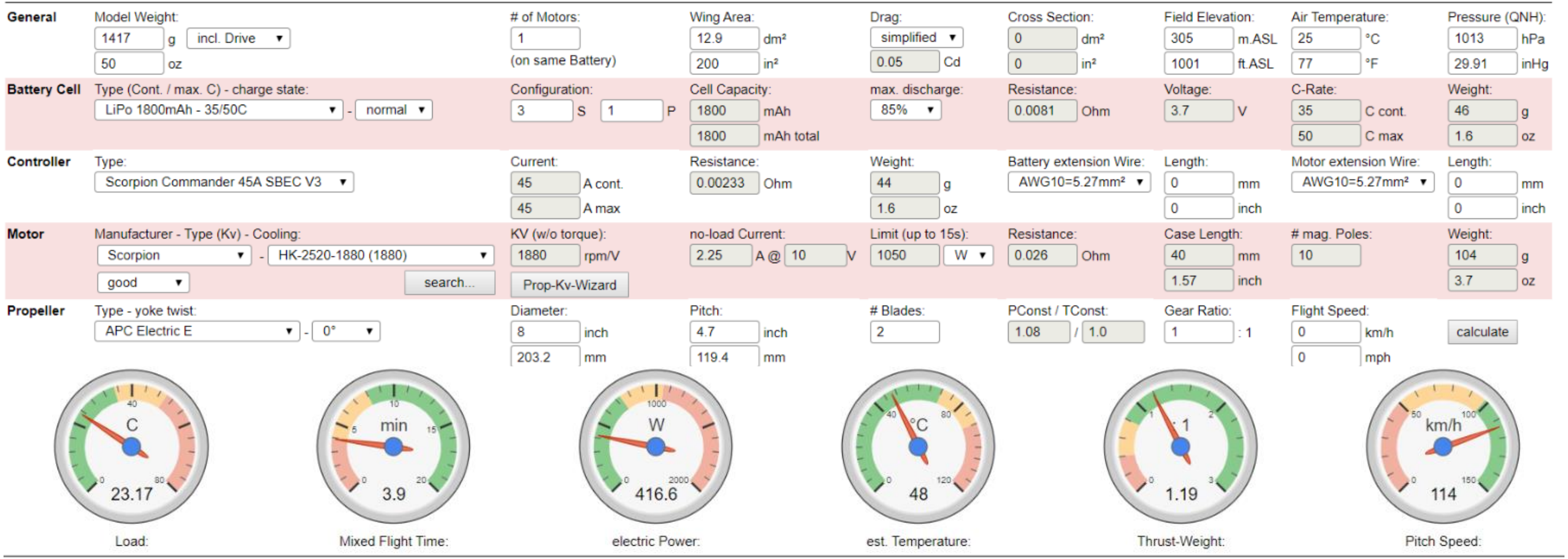
Drive Design

Propeller→ Motor→ **Electronic Speed Controller (ESC)→ Battery**



Selected ESC: Scorpion Commander 15V 45A ESC w/SBEC

Selected Battery: Lumenier 1800mAh 3-cell 35c Lipo Battery

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Drive Selection

Table 3: Drive Selection

Drive Part	Brand/Model	Size	Weight (oz)	Cost ($)
Prop	APC Electric SF 8x4.7	8” dia x 4.7” pitch	0.25	2.45
Motor	Scorpion HK-2520-1880KV	1” dia, 0.8” length (0.63 in^3)	3.64	80.00
ESC	Scorpion Commander 15V 45A ESC SBEC (V3)	2.83”x1.18”x0.32” (1.06 in^3)	1.55	60.00
Battery	Lumenier 1800mAh 3s 35c Lipo Battery	4.1”x1.34”x0.79” (4.34 in^3)	4.94	20.00
Total		6.03 in^3	10.38	162.45

Figure 4: APC Electric 8x4.7 SF

Figure 5: Scorpion Motor

Figure 6: Scorpion ESC

Figure 7: Lumenier Battery

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Fuselage Design

Primary functions:

- House drive components and wiring
- Connect with wing assembly
- Connect with landing gear
- Support loading upon landing
- Hold entire plane together

Components:

- Frame
- Drive housing
- Cover material
- Carbon fiber rod
- PVC payload

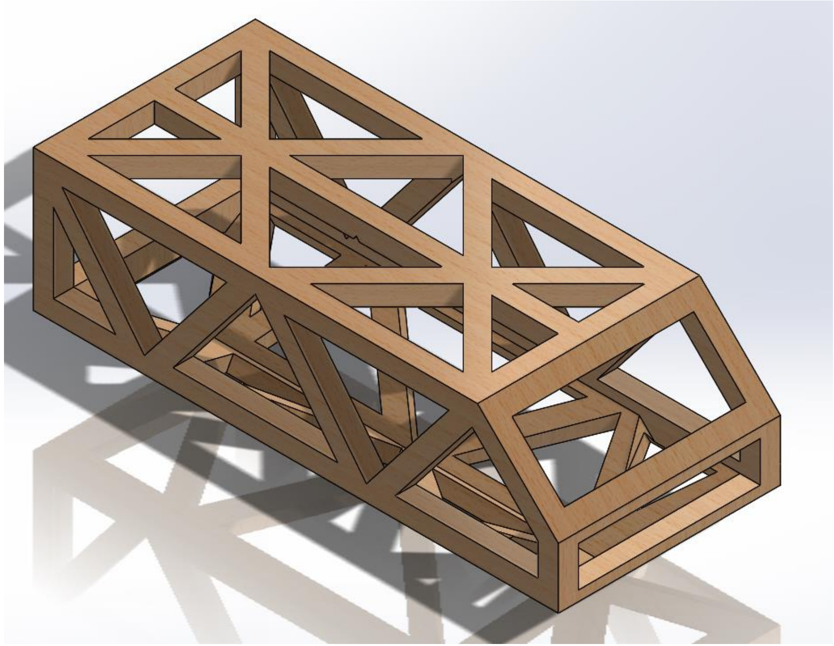

Figure 8: Fuselage Frame

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Fuselage Material Selection

Balsa:

- High manufacture time
- Low manufacture accuracy
- Low density→ low weight (0.03 lb total)
- Low yield strength (20 MPa)

ABS:

- Low manufacture time, rapid prototyping
- High manufacture accuracy
- High density→ more weight (0.22 lb total)
- Moderate yield strength (40 MPa)

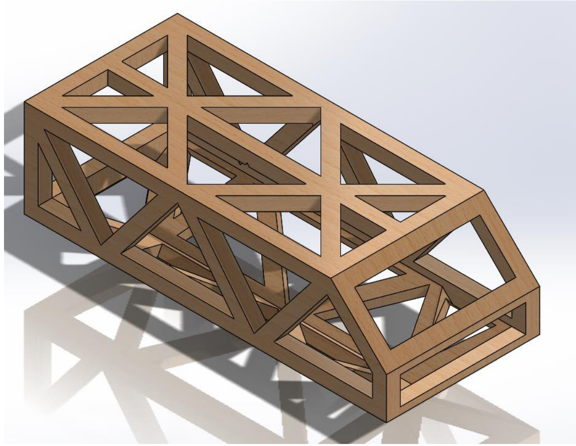

Figure 9: Balsa Frame

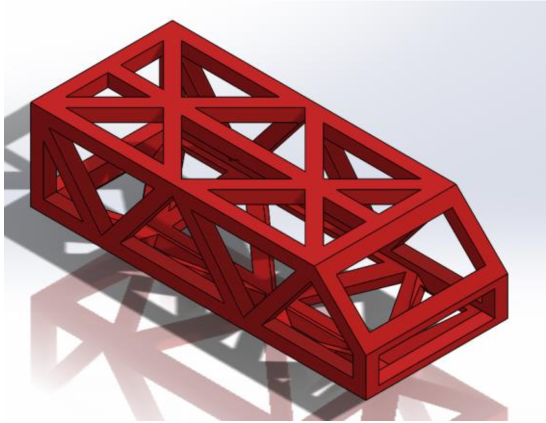

Figure 10: ABS Frame

Selected material→ ABS

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Fuselage Design

<u>CAD model</u>

- Verify carbon fiber rod and payload mounting
- Verify motor, ESC, battery, and receiver storage

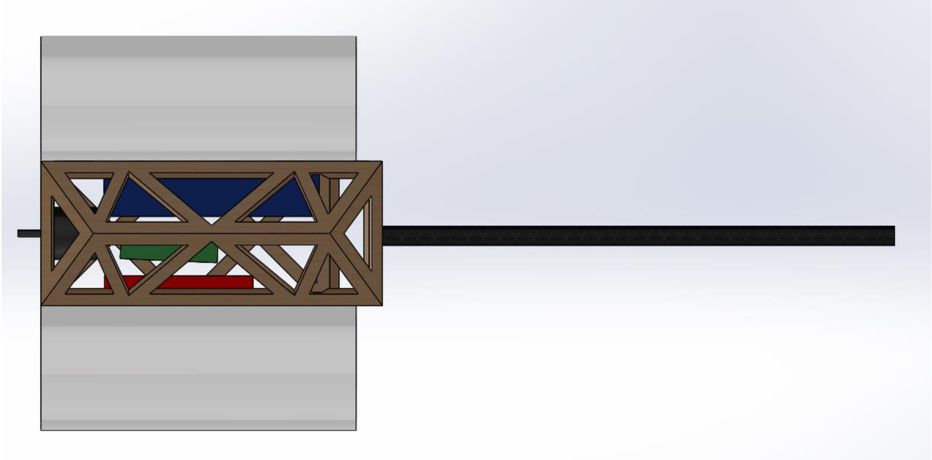

Figure 12: Fuselage Assembly (Bottom)

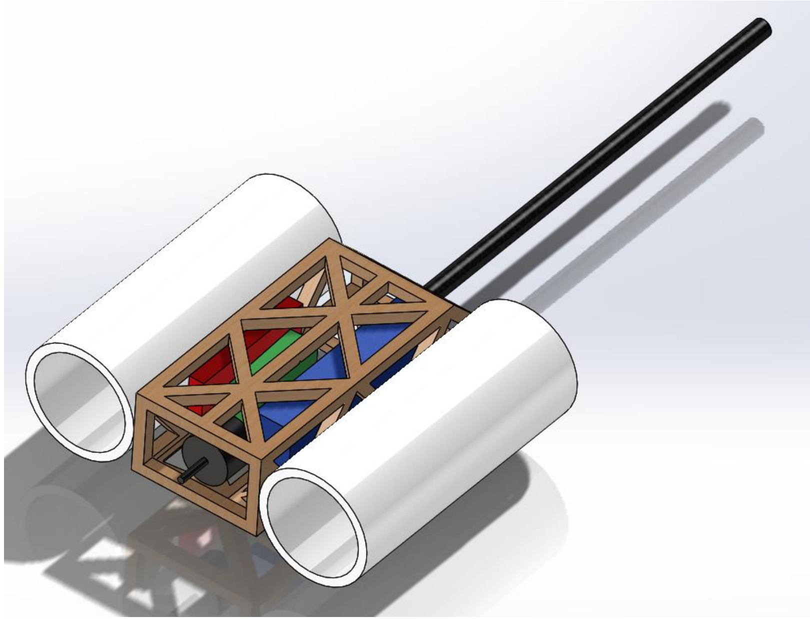

Figure 11: Fuselage Assembly (Top)

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Wing Design

<u>Airfoil Design</u>

- Clark Y Airfoil
  - Provides a smooth stall entry for RC plane
  - Flat bottom, simple for manufacturing, but provides a sufficient amount of lift
  - Square planform area
- Airfoil modifications
  - Ailerons with a rectangular wing: easier and faster
- Wing Materials:
    - Balsa Wood frame and exterior

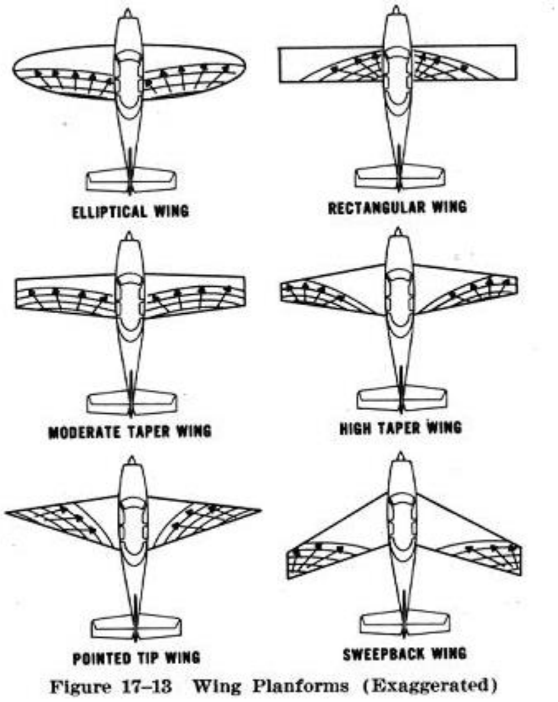

Figure 13: Airfoil Wing Design

Eli

Wing Design

<u>Wing Calculations</u>

- Wingspan = 52 inches
- Chord Length = 5.9 inches
- Planform Area = 306.8 squared inches
- Aspect Ratio = 8.814

<u>Balsa:</u>

- High manufacture time
- Readily available
- Low density→ low weight

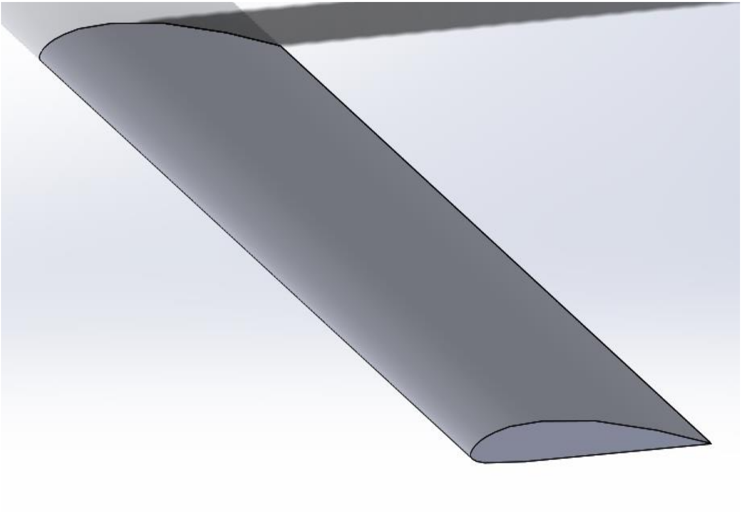

Figure 14: Airfoil Wing Design

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Landing Gear Design

Tail Dragger Design

- Two base wheels with an additional supporting wheel
- 3-4 inch height
- RC wheels that have an outer diameter of 1-1.5 inches

Landing Gear Material

- Aluminum Alloys
  - Rods or Thin connectors

Figure 15: Ideal Aircraft

Figure 16: Front Wheeled Design

Figure 17: Tail Dragger

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In-Flight Control Design

Primary functions:

- Maneuver plane through sky
- Increase/decrease altitude

Components:

- Servo Motors
- Shafts
- Tabs

Figure 18: Miuzei 10 pcs SG90 9G Servo Motor Kit *$18.00 amazon*

Figure 19: 10 pcs push and pull rods *$5.00 amazon*

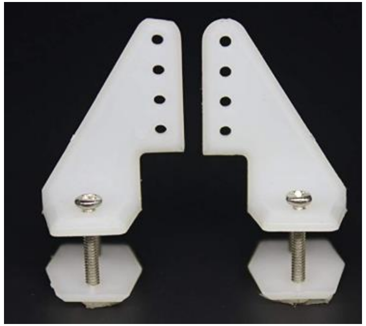

Figure 20: 10 pcs control horns

$5.00 amazon

Corbin

Design Requirements: CRs

Table 4: Customer Requirements

Gross Weight Limit (10 lbs)
In-flight radio control (2.4 GHz) w/ fail safe
wheeled landing gear steering mechanism
Payload cannot aid frame integrity
Payload attached w/ metal hardware
Electric motor/Servo
Red arming plug
3 cell 2200mAh lithium polymer battery
gyroscopic assist allowed
ASTM D1785 PVC Payload weights
Hand launch
12.125 in X 3.625 in X 13.875 in container
3 min assembly
1 min to energize, check, and launch
fly for 400-foot leg of a flight circuit
cost within budget
durable and robust design
reliable design
safe to operate

Figure 21: Metal Snaps

Figure 7: 1800 mAh Lumenier Battery

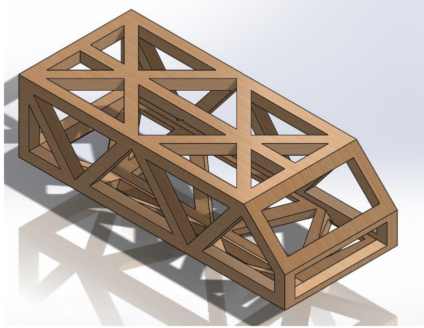

Figure 8: Fuselage Design

Figure 5: Scorpion Motor

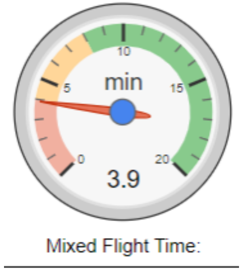

Figure 22: Estimated Flight time from Ecalc

Figure 23: Safety Precaution

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Design Requirements: ERs

Table 5: Engineering Requirements

Criteria (ERs)
Frequency (GHz)
Power (Watts)
Weight (lbs)
Time (seconds)
Capacity (mAh)
Storage Volume (in^3)
Length (inch)
Current (Amperes)
Angle (deg)
Acceleration (feet/second^2)
Angular Velocity (degrees/sec)
Angular Speed (rpm)
Lift (lb)
Thrust (lb)
Cost ($)
Toughness (in*lb/in^2)

$$Power\ needed\ to\ fly = 400\ W \quad (1)$$

$$Max\ Motor\ Power = 800\ W \quad (2)$$

$$All\ Up\ Weight\ (AUW) = 4\ lb \quad (3)$$

$$Max\ Weight\ Allowed = 10\ lb \quad (4)$$

$$Max\ Battery\ Capacity\ = 2200\ mAh \quad (5)$$

$$Design\ Battery\ Capacity = 1800\ mAh \quad (6)$$

$$Fuselage\ Storage\ Volume = 2.25\ in\ \times 6in\ \times 2in = 27in^3 \quad (7)$$

$$Used\ Space\ Within\ Fuselage = 6.03\ in^3 \quad (8)$$

$$Specific\ Thrust = .20\frac{oz}{W} \quad (9)$$

$$Optimum\ Motor\ Output = 280\ W \quad (10)$$

$$Thrust\ Genereated = Specific\ Thrust * Optimum\ Motor\ Output = 56\ oz \quad (11)$$

$$AUW = 60\ oz \quad (12)$$

$$Thrust{:}Weight = \frac{Thrust}{AUW} = 0.93 \quad (13)$$

Table 6: Equation References

Equation	Source
1	Ecalc
2	Scorpion site
3	Benchmarking NAU
4	SAE rules
5	SAE rules
6	Ecalc
7	
8	
9	Ecalc
10	Ecalc
11	Ecalc
12	Benchmarking NAU
13	Ecalc

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Design Validation FMEA: Risk Tradeoff

1. Incapable of generating thrust
2. Aircraft loses altitude
3. lack of control and aerodynamics
4. Plane landing on underbelly
5. Battery/Motor will combust
6. Motor will smoke and overheat

Table 7: Failure Mode and Effects Analysis

SAE Aero Micro		Prop Dogs				Page No of			
System Name						FMEA Number			
Subsystem Name									4-Nov-19
Component Name									
Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Severity (S)	Potential Causes and Mechanisms of Failure	Occurance (O)	Current Design Controls Test	Detection (D)	RPN	Recommended Action
#1: Propellor	Crack	Aircraft falling out of the sky	5	Tolerance Buildup	8		4	160	Revise Test Plan
#6: Fuselage	Brittle Fracture	Debris falling from the sky	7	Poor maintenance	3		3	63	Revise Test Plan
#5: Wings	Crack/Fracture	Aircraft falling out of the sky	7	Assembly/Building Errors	4		3	84	Revised Subassembly design
#6: Lower Fuselage Frame/Landing Gear	Buckling	Shrapnel flying when landing	5	Assembly errors/Lack of testing	5		7	175	Revised Subassembly design
#12: ESC	Over Amperage/Voltage	Aircraft on fire	8	User Error (preflight)	2		5	80	Replace parts
#4: Servo Motor	Overload	Aileron Malfunction	3	User Error (preflight)	3		2	18	Replace parts

Eli

Risk FMEA: Future Testing

Future Testing:

- Testing the Stress and Strain
  - landing gear, aileron mechanisms, and wing frame
- Running the drive system
  - Wheeled base with a propellor (aircraft on the ground)
  - Ground checks of ailerons
- Experimentation of flight
  - Flying prototypes to prevent failure in the fuselage and frame
- Airfoil experimentation
  - Justifying that the airfoil is ideal for our design

Resources and equipment

- Soils lab (measuring devices) and 98C (wind tunnel)

Table 7a: Failure Mode and Effects Analysis

Part # and Functions	RPN	Recommended Action
#1: Propellor	160	Revise Test Plan
#6: Fuselage	63	Revise Test Plan
#5: Wings	84	Revised Subassembly design
#6: Lower Fuselage Frame/Landing Gear	175	Revised Subassembly design
#12: ESC	80	Replace parts
#4: Servo Motor	18	Replace parts

Eli

Bill of Materials (BOM) and Budget

Table 8: Bill of Materials

Bill of Materials							
Team: Prop Dogs							
Part #	**Part Name**	**Qty**	**Description**	**Functions**	**Material**	**Dimensions**	**Cost ($)**
1	Propeller	1	APC Electric Sf 8x4.7	Creates thrust	Plastic	8" diameter	2.45
2	Electric Motor	1	Scorpion HK-2520-1880 KV	rotates the propeller	Aluminum	1"x.8" (Cylindrical)	80
3	RC Controller/Receiver	1	Black controller	Controls the electrical components	Plastic, Metal, electrical Wirin	6"x6"	230
4	Servo Motor	3	Miuzei SG90	Converts the Mechanical motion into digita	Plastics, and metal	1"x1" and 8" wire	11.95
5	Wing Frame	2	Small stick components for the frame	Creates Lift	Balsa Wood	1/8" x 1/8" x 36"	19.18
6	Fuselage Frame	1	Thin curved wood	Creates lift/holds payload	Balsa Wood	300x200x1.5mm	12
7	Snaps	10	Metal fasteners	Connects the parts of the plane	Plastic	Diameter = 7/16"	7.99
8	Air Foil (Shrink wrap, tape)	1	Film	Creates an aerodynamic design	Polyethylene	2"x180'	11
9	Wiring	1	Thin, copper wiring	Actuates the Electrical Components	Copper/Aluminum	75"	5.91
10	Battery	1	Lumenier 1800mAh Lipo Battery	Stores Voltage	Plastic, Metal, electrical Wirin	4.1"x1.34"x.079"	20
11	Adhesive	1	Glue	Holds the internal frame in place	glue	N/A	
12	ESC	1	Scorpion Commander 15V 45A	Trasnmits appropriate Amperage to Motors	Plastic, Metal, electrical Wirin	2.83"x1.18"x0.32"	60
13	PVC Pipe	1	Payload PVC	Payload	PVC	2"D x 12"	9.25
14	Wheels	3	Small rotating wheels	Prevents plane from crashing when landing	rubber/metal	3" outer D	4.56

Total allowance: $2000

Cost of registration: $1100

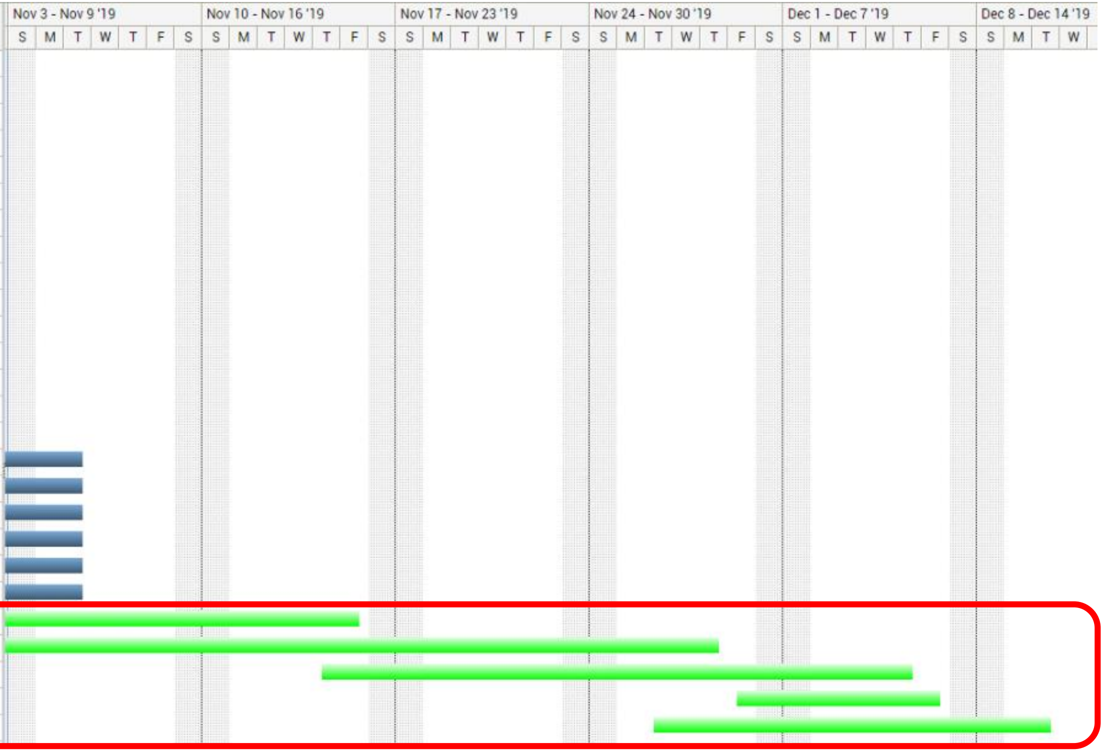
Total cost $474.29

Funds remaining $425.71

Corbin

Schedule and Important Dates

	Name	Duration	Start	Finish
1	Customer Needs	2days	09/16/2019	09/17/2019
2	Engineering Requirements	2days	09/16/2019	09/17/2019
3	Project Description	2days	09/16/2019	09/17/2019
4	Background	2days	09/16/2019	09/17/2019
5	Literature Review	2days	09/16/2019	09/17/2019
6	Schedule	2days	09/16/2019	09/17/2019
7	Budget	2days	09/16/2019	09/17/2019
8	Benchmarking	2days	09/16/2019	09/17/2019
9	Concept Generation	11days	09/17/2019	10/01/2019
10	Concept Evaluation	6days	10/01/2019	10/08/2019
11	Budget Planning	16days	09/17/2019	10/08/2019
12	Prototype	9days	10/08/2019	10/18/2019
13	Preliminary Report	9days	10/08/2019	10/18/2019
14	Analyses Team Memo	6days	10/18/2019	10/25/2019
15	Website Check 1	6days	10/25/2019	11/01/2019
16	CAD package	21days	10/08/2019	11/05/2019
17	BOM	12days	10/21/2019	11/05/2019
18	Design Validation	12days	10/21/2019	11/05/2019
19	Design Requirements	12days	10/21/2019	11/05/2019
20	Schedule for next Semester	7days	10/28/2019	11/05/2019
21	Budget for next Semester	7days	10/28/2019	11/05/2019
22	Final Report	11days?	11/01/2019	11/15/2019
23	Final BOM/Cad package	21days?	10/31/2019	11/28/2019
24	Final Prototype	16days?	11/14/2019	12/05/2019
25	Website check 2	6days?	11/29/2019	12/06/2019
26	Analytical report	11days?	11/26/2019	12/10/2019



Corbin

Questions?