



AIAA Design/Build/Fly Competition
2020-2021 Aircraft Design Report

Brigham Young University Aeronautics Club
2021 AIAA Design Build Fly Competition Design Report

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I Executive Summary

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II Management Summary

II.A Team Organization

Figure 1 depicts the overall organization of our team structure. Each of the teams is lead by an individual who answers to the Engineering Lead and Project Manager. The skills required for each position/team are as follows.

Engineering Lead As with the team leads, the Engineering Lead primarily requires good decision making and leadership skills, qualities the BYU Aero Club seeks to develop in all of its members. In addition the Engineering Lead has a well rounded understanding of the various systems and both design and testing expertise.

Project Manager The Project Manager has excellent organizational skills and oversees the logistical side of the project: heading up report writing, budgeting tasks, scheduling, etc.

Aerodynamics The Aerodynamics team members have expertise in aerodynamic analysis and testing, including skills in hand calculations, computational analysis tools, wind tunnel and glide testing.

Structures The Structures team members focus on skills in structural analysis and testing, employing hand calculations, computational tools, and various structural testing methods.

Propulsion The Propulsion team focuses on analyzing and testing the propulsion system effectiveness and efficiency, but also has skills in electronics related to the propulsion system.

Systems The Systems team works very closely with the Engineering Lead, as they oversee all systems interfacing, avionics, etc. There is a sub-group of the Systems team that is assigned to work on the mission specific payload and related components, as well as related testing.

Manufacturing The Manufacturing team oversees the manufacturing of all prototypes and testing apparatus.

Graphics The Graphics team has skills in CAD design as well as graphical marketing for the team.

II.B Schedule

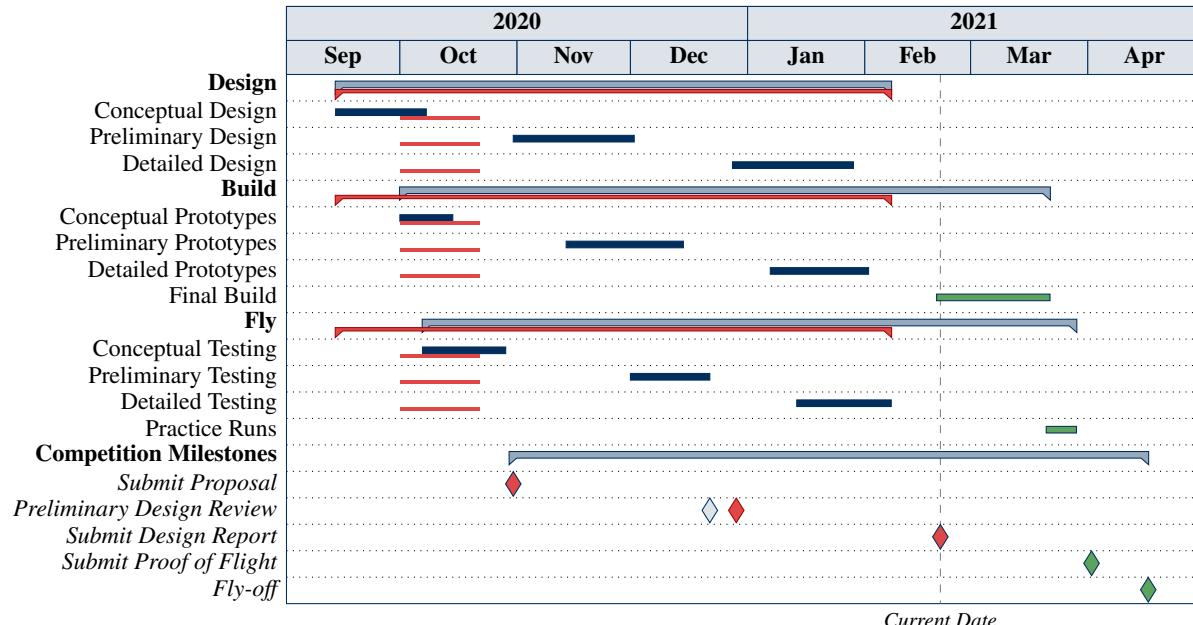


Figure 2 This milestone chart reveals our **original plan** for major elements of our design process compared to the **actual timing** of these events. Note that we submitted the proposal on time, as well as this report. We anticipate remaining on schedule for the **future elements** of this chart.

Figure 2 depicts our planned vs. actual timeline for the year. Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi



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III Conceptual Design

III.A Mission Requirements

The mission requirements for this year's competition are as follows:

III.A.1 Airframe and Operational Constraints:

- Safety Requirements:
 - [THIS YEAR'S REQUIREMENT(S).]
- Airframe Requirements:
 - [THIS YEAR'S REQUIREMENT(S).]
- Payload Requirements:
 - [THIS YEAR'S REQUIREMENT(S).]
- [THIS YEAR'S SPECIAL REQUIREMENT(S)]:
 - [THIS YEAR'S REQUIREMENT(S).]

III.A.2 Flight Mission Scoring:

Flight Mission 1:

Flight Mission 2:

Flight Mission 3:

III.A.3 Total Score Summary:

$$TS = M_1 + M_2 + M_3 + GM + DR$$

where TS is total score, M_i is the score associated with the mission number subscript, GM is the ground mission score, and DR is the design report score.

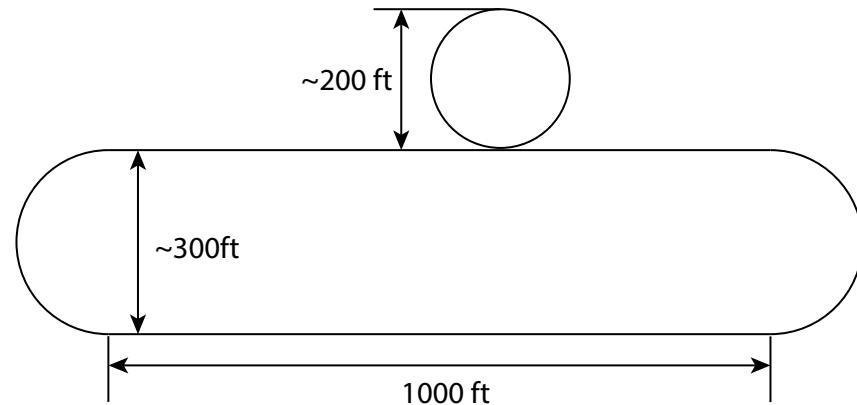


Figure 3 This plot breaks down the estimated lengths of the course based on the scale drawing from the mission requirements.

III.B Sub-system Design Requirements

We have organized our sub-system requirements into aerodynamics, structure, propulsion, and specialty requirements explained below.



III.B.1 Aerodynamics Requirements

Some of the major requirements for the aerodynamics sub-system are: Maximize aerodynamic efficiency in order to use less energy to overcome drag for all flight missions. Design wing loading to be able to take off and fly with design max payload weight. Keep the wingspan within the maximum of [MAX SPAN CONSTRAINT THIS YEAR]. Choose airfoil(s) and configuration that will make take off feasible in the [THIS YEAR'S TAKE-OFF REQUIREMENT]

III.B.2 Structural Requirements

The breakdown of mission requirements for the structures sub-system include: Minimize the structural weight while maintaining sufficient rigidity to keep the aerodynamics as designed, especially when full payload weight is in use. Make sure the structure is sufficiently rigid to avoid aerodynamic flutter within the flight envelope. [OTHER MISC. STRUCTURES REQUIREMENTS THIS YEAR (E.G. FOLDING WINGS.)]

III.B.3 Propulsion Requirements

The propulsion sub-system requirements are to: Have sufficient system efficiency and battery capacity to enable completion of the flight missions and maximizing speed with sufficient endurance while also providing sufficient thrust for [THIS YEAR'S TAKE-OFF REQUIREMENT]

III.B.4 Specialty Requirements

[REQUIREMENTS FOR THIS YEAR'S SPECIAL STUFF.] Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris.

III.C Scoring Sensitivity Analysis

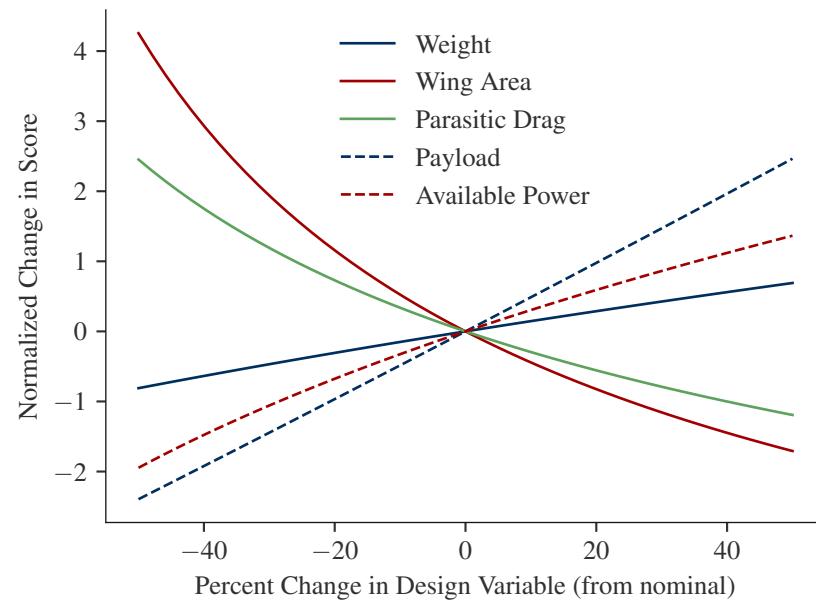


Figure 4 This plot shows the effects of those design parameters that directly affect the increase/decrease in mission scoring beyond simple completion.

For our sensitivity study, we first differentiated between design variables that could increase/decrease our score and those that were only related to the minimum constraints. Furthermore, some aspects of the score are insensitive by design parameters, such as the design report score, the ground mission score, and the Flight Mission 1 score. Our total, design-sensitive score is simply the sum of scores from Flight Mission 2 and 3.



[BREAKDOWN OF THE MATHS USED TO PERFORM THE SENSITIVITY STUDY.]

In order to normalize the scores as they are in the competition, we ran the analysis first without normalization, from which we saved the maximum scores like they are in competition. We then used those maxima as the normalization factors and re-ran the analysis. This way we could simulate the competition normalizations for the scoring and one mission would not dominate another unrealistically.

In our analysis (results shown in figure 4), we found that the wing area and parasitic drag coefficient induced negative sensitivities, thus we want to minimize drag and maximize wing loading (while still being able to take off). The available power was also important, and can be affected by increasing battery capacity, discharge rate, or voltage, or increasing propulsive efficiency. [TAKE AWAYS FROM PAYLOAD STUFF]. We should also note that the aircraft weight had the lowest effect on the overall sensitivity, but is incredibly important to meeting the fixed constraints of the competition.

III.D Concept Review, Weighting, and Selection Process

Informed by our sensitivity study, table 1 shows our general figures of merit for our conceptual design choices. In addition to the primary mission sensitive parameters, we added some practical figures of merit as well. In addition, rather than having multiple figures of the same value, we chose to make each figure a distinct value, thereby requiring a true prioritization and less change of ambiguity during the selection process.

We chose weight as the most important factor because it not only relates to the mission objectives, but also concerns the take-off/landing constraints. Drag was our next highest factor, as speed is important for maximizing flight mission scores. We placed simplicity next, as we must be able to actually produce our chosen design with our current and realistic potential abilities. We found stability to be important as well, since our aircraft needs to be controllable if we are to compete, but stability is relatively easy to achieve for most designs, so it was given a relatively lower value to match. Finally [TALK ABOUT THE YEAR SPECIFIC METRIC IF THERE IS ONE.] Each of the decision matrices has additional figures of merit associated with sub-system specific requirements. Note also, that parameters associated with available power were not included in the general list of figures of merit, but are included in propulsion specific decision matrices.

Table 1 Figures of Merit

| Factor | Scale (1-5) |
|----------------------|-------------|
| Weight | 10 |
| Drag | 8 |
| Simplicity | 6 |
| Stability | 4 |
| [YEAR SPECIFIC ITEM] | 2 |

III.D.1 Wing Configuration Selection

For our wing configuration, we needed to take overall potential lift into account, due to the take-off/landing requirements. Table 2 shows our scoring for single wing, tandem wing, and bi/tri-wing configurations. Note that we eliminated flying wing/blended wing body configurations up front based on our previous experience with that concept.

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Table 2 Weighted decision matrix for wing configuration.

| Factor | Scale | Single Wing | Tandem Wing | Bi/Tri-wing |
|----------------------|-------|-------------|-------------|-------------|
| | | | | |
| Weight | 10 | 3 | 2 | 1 |
| Drag | 8 | 3 | 2 | 1 |
| Simplicity | 6 | 3 | 1 | 2 |
| Lift | 5 | 2 | 2 | 3 |
| Stability | 4 | 3 | 2 | 3 |
| [YEAR SPECIFIC ITEM] | 2 | | | |
| Totals | | | | |

III.D.2 Wing Placement Selection

For the wing placement, we compared high, mid, and low wing placement. An addition figure of merit here is the accessibility, that is, the accessibility of the payload and electronics. This is important not only for the ground mission, but also for setting up the aircraft for flight.

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Table 3 Weighted decision matrix for wing placement.

| Factor | Scale | High Wing | Mid Wing | Low Wing |
|----------------------|-------|-----------|----------|----------|
| | | | | |
| Weight | 10 | 3 | 2 | 3 |
| Drag | 8 | 2 | 3 | 2 |
| Simplicity | 6 | 3 | 1 | 2 |
| Accessibility | 5 | 1 | 2 | 3 |
| Stability | 4 | 3 | 2 | 1 |
| [YEAR SPECIFIC ITEM] | 2 | | | |
| Totals | | | | |

III.D.3 Empennage Configuration Selection

For the tail configuration selection, we did not see the need for any further figures of merit. We compared three families of configuration: T-tail family, including conventional, cruciform, and T-tail designs; V-tail family, including V- and inverted V-tail designs; and H-tail family, including U-, H-, and inverted U-tail designs.

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Table 4 Weighted decision matrix for tail configuration.

| Factor | Scale | T-Tail Variations | | V-Tail Variations | | H-Tail Variations | |
|----------------------|-------|-------------------|---|-------------------|--|-------------------|--|
| | | | | | | | |
| Weight | 10 | 2 | 3 | | | 1 | |
| Drag | 8 | 2 | 3 | | | 2 | |
| Simplicity | 6 | 3 | 2 | | | 1 | |
| Stability | 4 | 2 | 1 | | | 3 | |
| [YEAR SPECIFIC ITEM] | 2 | | | | | | |
| Totals | | | | | | | |

III.D.4 Propulsion Configuration Selection

For the propulsion configuration, drag did not make sense as a figure of merit, since the system is in direct opposition to drag. Therefore we exchanged drag for efficiency, since efficiency directly affects available power (which we found to be important in section 3.3). We also included lift as a figure of merit for the propulsion system, because blown wing configurations can experience increased lift (due to higher induced velocities over the wing).

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Table 5 Weighted decision matrix for propulsion configuration.

| Factor | Scale | Single Prop | | Dual Prop | | Distributed Prop | |
|-----------------------|-------|-------------|--|-----------|--|------------------|--|
| | | | | | | | |
| Weight | 10 | 3 | | 2 | | 1 | |
| Propulsive Efficiency | 8 | 1 | | 2 | | 3 | |
| Lift | 7 | 1 | | 2 | | 3 | |
| Simplicity | 6 | 3 | | 2 | | 1 | |
| Stability | 4 | 3 | | 2 | | 3 | |
| [YEAR SPECIFIC ITEM] | 2 | | | | | | |
| Totals | | | | | | | |



III.D.5 Propulsion Placement Selection

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Table 6 Weighted decision matrix for propulsion placement.

| Factor | Scale | Pull Variations | Push Variations | Combinations |
|-----------------------|-------|-----------------|-----------------|--------------|
| | | | | |
| Weight | 10 | 3 | 3 | 3 |
| Lift | 4 | 3 | 1 | 2 |
| Simplicity | 6 | 3 | 2 | 1 |
| Propulsive Efficiency | 4 | 3 | 1 | 2 |
| [YEAR SPECIFIC ITEM] | 2 | | | |
| Totals | | | | |

III.D.6 Payload

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Table 7 Weighted decision matrix for [SPECIFY THIS YEAR'S PAYLOAD DESIGN].

| Factor | Scale | [OPTION] | [OPTION] | [OPTION] |
|----------------------|-------|---|---|---|
| | | <i>Figure Placeholder</i> Aspect ratio = 4:3 | <i>Figure Placeholder</i> Aspect ratio = 4:3 | <i>Figure Placeholder</i> Aspect ratio = 4:3 |
| Weight | 10 | | | |
| Strength | 8 | | | |
| Simplicity | 6 | | | |
| Durability | 4 | | | |
| [YEAR SPECIFIC ITEM] | 2 | | | |
| Totals | | | | |

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III.D.7 Final Concept

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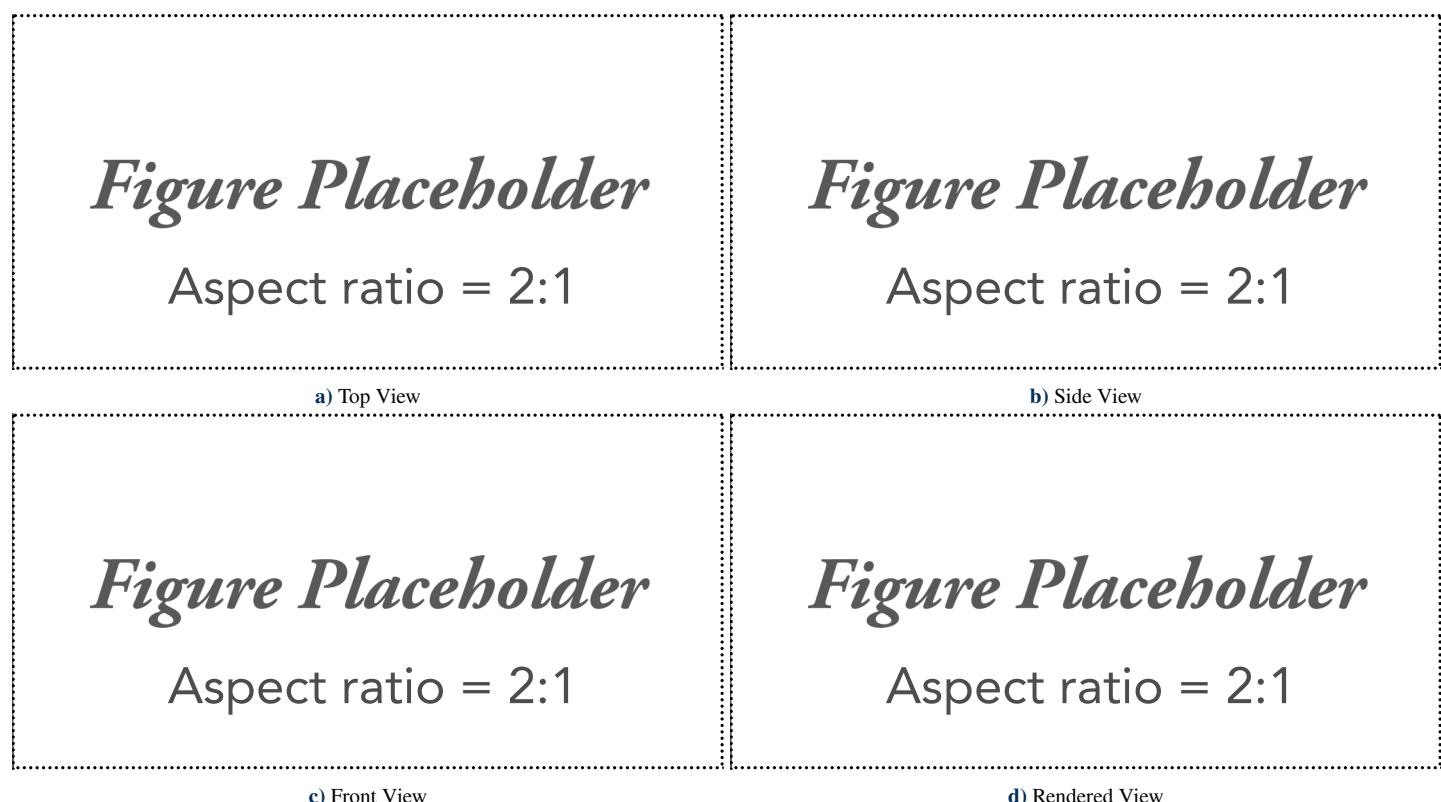


Figure 5 Drawings and rendering of our conceptual aircraft design.

IV Preliminary Design

IV.A Methodology

IV.A.1 Quantify Basic Constraints

The sensitivity study presented in section 3.3 did not include any constraints, but rather simple sensitivities that informed our conceptual design choices. To begin a preliminary design, we first needed to translate the given constraints (listed in section 3.2) into mathematical formulas for rapid comparison and trade studies. Aside from the obvious constraints (such as the wing span constraint), we determined the following to be important expressions.



Figure Placeholder

Aspect ratio = 4:3

Figure 6 Preliminary design process flow chart.

Stall Speed

$$V_{\text{stall}} = \left[\frac{2W}{\rho S_{\text{ref}} C_{L_{\max}}} \right]^{1/2}$$

Where V_{stall} is the stall speed, W is the total aircraft weight, ρ is the ambient air density, S_{ref} is the reference wing area, and $C_{L_{\max}}$ is the maximum aircraft lift coefficient.

Take-off Distance

$$d_{LO} = \frac{W^{5/2}}{(\rho S_{\text{ref}} C_{L_{\max}})^{3/2} P_{\text{net}}}$$

Where d_{LO} is the distance to lift-off, P_{net} is the net power, that is, the power accounting for both thrust and drag, and the other variables are as defined previously.

Maximum Speed

$$V_{\max} = \left[\frac{\frac{T_a}{S_{\text{ref}}} + \frac{W}{S_{\text{ref}}} \sqrt{\left(\frac{T_a}{W}\right)^2 - 4C_{D_0}K}}{\rho C_{D_0}} \right]^{1/2}$$

Where V_{\max} is the maximum velocity, T_a is the available thrust, C_{D_0} is the zero-lift drag coefficient of the aircraft, and K is an empirical constant assumed here to be 0.38.

Maximum Range

$$R = \frac{e_b}{g} \eta \frac{L}{D} \frac{m_b}{m_{\text{tot}}}$$

Where R is the total range; e_b is the battery energy per unit mass; g is the gravitational constant; η is the combination of efficiency factors from the battery, motor, and propeller ($\eta = \eta_b \eta_m \eta_p$); L/D is the aircraft lift to drag ratio, and m_b/m_{tot} is ratio of the battery mass to total aircraft mass.

C_L for Maximum Efficiency (and Range)

$$C_{L_{\max \text{ L/D}}} = [C_{D_p} \pi S_{\text{ref}} Re]^{1/2}$$

Where C_{D_p} is the parasitic drag coefficient for the aircraft, Re is the Reynolds number, and other variables are defined previously.

Climb Rate

$$v_z = \frac{V_{\infty} (T - D)}{W}$$

Where v_z is the vertical climb rate, V_{∞} is the flight velocity of the aircraft, T is the thrust force magnitude, and D is the drag force magnitude.



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Coordinated Turn Radius

$$r_{\text{turn}} = \frac{V^2}{g \tan \phi}$$

Where r_{turn} is the turn radius, V is the aircraft speed, and ϕ is the bank angle of the aircraft.

Coordinated Turn Load Factor

$$n = \frac{1}{\cos \phi}$$

Where n is the load factor.

IV.A.2 Analysis Models

Weight Estimation

Propulsion Model

Vortex Lattice Method (XFLR5, AVL, or VLM.jl)

Structures Stuff (Beams, composites, etc.)

Code

IV.B Trade Studies

maximize : $M2 + M3$

with respect to : $W, S_{\text{ref}}, C_{D_0}, [\text{PAYLOAD STUFF}], P_a$ (1)

subject to : $V_{\text{stall}}, V_{\text{maneuver}}, d_{LO}, R, r_{\text{turn}}$

where V_{maneuver} is the maximum velocity boundary associated with structural failure due to maneuver acceleration.

IV.B.1 Wing/Tail Design

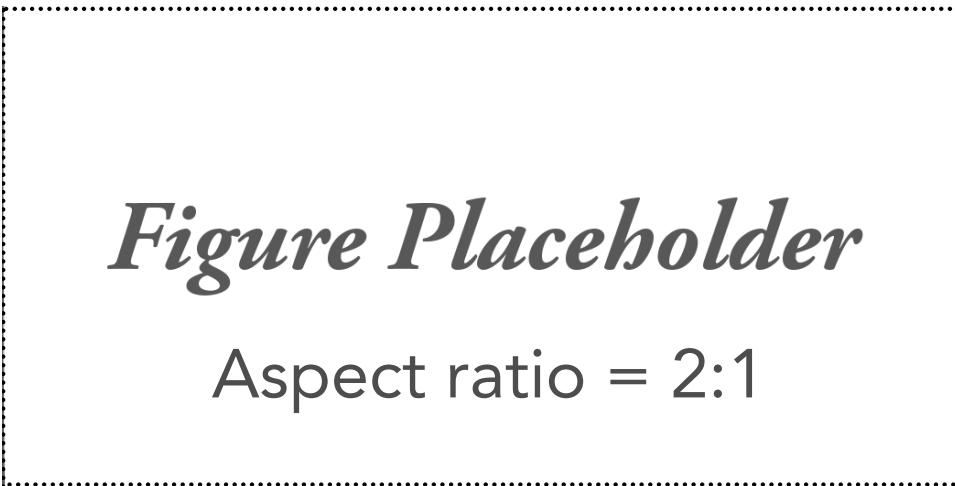


Figure 7 Airfoil geometry comparison.

Airfoil(s)

Sizing

IV.B.2 Propulsion

IV.B.3 Fuselage

IV.B.4 Payload

IV.B.5 [OTHER TRADE STUDIES TO FIND THE ANSWER TO THE OPTIMIZATION PROBLEM.]



Figure Placeholder

Aspect ratio = 4:3

Figure Placeholder

Aspect ratio = 4:3

a) c_{ℓ} vs α

b) c_{ℓ} vs c_d

Figure 8 Airfoil Polar comparison.

Table 8 Preliminary wing and tail sizes.

| Parameter | Wing | Vertical Tail | Horizontal Tail |
|-----------------------------|------|---------------|-----------------|
| Span (ft) | | | |
| Root Chord (ft) | | | |
| Tip Chord (ft) | | | |
| Wing Area (ft^2) | | | |
| Aspect Ratio | | | |

Figure Placeholder

Aspect ratio = 2:1

Figure 9 Lift distribution at cruise for each mission.

Table 9 Preliminary propulsion system comparison.

| Motor | Kv | Battery | Current (Amps) | Propeller | Static Thrust (lbs) | Total Weight (lbs) |
|-------|----|---------|----------------|-----------|---------------------|--------------------|
| | | | | | | |



Figure Placeholder

Aspect ratio = 4:3

Figure 10 Efficiency curves for the motor and propeller selection.

IV.C Estimated Aircraft Performance

IV.C.1 Performance Prediction Methodologies and Uncertainties

IV.C.2 Lift and Drag

Table 10 Estimated total lift and drag values.

| Parameter | Mission 1 | Mission 2 | Mission 3 |
|-----------------------|-----------|-----------|-----------|
| $C_{L_{\max}}$ | | | |
| $C_{L_{\text{avg}}}$ | | | |
| C_{D_0} | | | |
| L/D_{cruise} | | | |
| Efficiency Factor (e) | | | |

Lift Analysis

Figure Placeholder

Aspect ratio = 2:1

Figure 11 Drag breakdown for each mission

Drag Analysis

IV.C.3 Stability



Figure Placeholder

Aspect ratio = 2:1

Figure 12 Moment coefficient vs α

Table 11 Stability derivatives for Flight Mission 1.

| | Angle of Attack | V_{TO}/V_C | Side Slip Angle | V_{TO}/V_C | Roll Rate | V_{TO}/V_C | Pitch Rate | V_{TO}/V_C | Yaw rate | V_{TO}/V_C |
|-----------------|------------------|---------------|-----------------|---------------|--------------|---------------|--------------|---------------|--------------|---------------|
| Lift Force | $C_{L\alpha}$ | 0.0000/0.0000 | $C_{L\beta}$ | 0.0000/0.0000 | C_{Lp} | 0.0000/0.0000 | C_{Lq} | 0.0000/0.0000 | C_{Lr} | 0.0000/0.0000 |
| Drag Force | $C_{D\alpha}$ | 0.0000/0.0000 | $C_{D\beta}$ | 0.0000/0.0000 | C_{Dp} | 0.0000/0.0000 | C_{Dq} | 0.0000/0.0000 | C_{Dr} | 0.0000/0.0000 |
| Lateral Force | $C_{Y\alpha}$ | 0.0000/0.0000 | $C_{Y\beta}$ | 0.0000/0.0000 | C_{Yp} | 0.0000/0.0000 | C_{Yq} | 0.0000/0.0000 | C_{Yr} | 0.0000/0.0000 |
| Rolling Moment | $C_{\ell\alpha}$ | 0.0000/0.0000 | $C_{\ell\beta}$ | 0.0000/0.0000 | $C_{\ell p}$ | 0.0000/0.0000 | $C_{\ell q}$ | 0.0000/0.0000 | $C_{\ell r}$ | 0.0000/0.0000 |
| Pitching Moment | $C_{m\alpha}$ | 0.0000/0.0000 | $C_{m\beta}$ | 0.0000/0.0000 | C_{mp} | 0.0000/0.0000 | C_{mq} | 0.0000/0.0000 | C_{mr} | 0.0000/0.0000 |
| Yawing Moment | $C_{n\alpha}$ | 0.0000/0.0000 | $C_{n\beta}$ | 0.0000/0.0000 | C_{np} | 0.0000/0.0000 | C_{nq} | 0.0000/0.0000 | C_{nr} | 0.0000/0.0000 |

Table 12 Stability derivatives for Flight Mission 2.

| | Angle of Attack | V_{TO}/V_C | Side Slip Angle | V_{TO}/V_C | Roll Rate | V_{TO}/V_C | Pitch Rate | V_{TO}/V_C | Yaw rate | V_{TO}/V_C |
|-----------------|------------------|---------------|-----------------|---------------|--------------|---------------|--------------|---------------|--------------|---------------|
| Lift Force | $C_{L\alpha}$ | 0.0000/0.0000 | $C_{L\beta}$ | 0.0000/0.0000 | C_{Lp} | 0.0000/0.0000 | C_{Lq} | 0.0000/0.0000 | C_{Lr} | 0.0000/0.0000 |
| Drag Force | $C_{D\alpha}$ | 0.0000/0.0000 | $C_{D\beta}$ | 0.0000/0.0000 | C_{Dp} | 0.0000/0.0000 | C_{Dq} | 0.0000/0.0000 | C_{Dr} | 0.0000/0.0000 |
| Lateral Force | $C_{Y\alpha}$ | 0.0000/0.0000 | $C_{Y\beta}$ | 0.0000/0.0000 | C_{Yp} | 0.0000/0.0000 | C_{Yq} | 0.0000/0.0000 | C_{Yr} | 0.0000/0.0000 |
| Rolling Moment | $C_{\ell\alpha}$ | 0.0000/0.0000 | $C_{\ell\beta}$ | 0.0000/0.0000 | $C_{\ell p}$ | 0.0000/0.0000 | $C_{\ell q}$ | 0.0000/0.0000 | $C_{\ell r}$ | 0.0000/0.0000 |
| Pitching Moment | $C_{m\alpha}$ | 0.0000/0.0000 | $C_{m\beta}$ | 0.0000/0.0000 | C_{mp} | 0.0000/0.0000 | C_{mq} | 0.0000/0.0000 | C_{mr} | 0.0000/0.0000 |
| Yawing Moment | $C_{n\alpha}$ | 0.0000/0.0000 | $C_{n\beta}$ | 0.0000/0.0000 | C_{np} | 0.0000/0.0000 | C_{nq} | 0.0000/0.0000 | C_{nr} | 0.0000/0.0000 |



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Table 13 Stability derivatives for Flight Mission 3.

| | Angle of Attack | V_{TO}/V_C | Side Slip Angle | V_{TO}/V_C | Roll Rate | V_{TO}/V_C | Pitch Rate | V_{TO}/V_C | Yaw rate | V_{TO}/V_C |
|-----------------|-------------------|---------------|------------------|---------------|--------------|---------------|--------------|---------------|--------------|---------------|
| Lift Force | C_{L_α} | 0.0000/0.0000 | C_{L_β} | 0.0000/0.0000 | C_{L_p} | 0.0000/0.0000 | C_{L_q} | 0.0000/0.0000 | C_{L_r} | 0.0000/0.0000 |
| Drag Force | C_{D_α} | 0.0000/0.0000 | C_{D_β} | 0.0000/0.0000 | C_{D_p} | 0.0000/0.0000 | C_{D_q} | 0.0000/0.0000 | C_{D_r} | 0.0000/0.0000 |
| Lateral Force | C_{Y_α} | 0.0000/0.0000 | C_{Y_β} | 0.0000/0.0000 | C_{Y_p} | 0.0000/0.0000 | C_{Y_q} | 0.0000/0.0000 | C_{Y_r} | 0.0000/0.0000 |
| Rolling Moment | C_{ℓ_α} | 0.0000/0.0000 | C_{ℓ_β} | 0.0000/0.0000 | C_{ℓ_p} | 0.0000/0.0000 | C_{ℓ_q} | 0.0000/0.0000 | C_{ℓ_r} | 0.0000/0.0000 |
| Pitching Moment | C_{m_α} | 0.0000/0.0000 | C_{m_β} | 0.0000/0.0000 | C_{m_p} | 0.0000/0.0000 | C_{m_q} | 0.0000/0.0000 | C_{m_r} | 0.0000/0.0000 |
| Yawing Moment | C_{n_α} | 0.0000/0.0000 | C_{n_β} | 0.0000/0.0000 | C_{n_p} | 0.0000/0.0000 | C_{n_q} | 0.0000/0.0000 | C_{n_r} | 0.0000/0.0000 |

Table 14 Dynamic stability characteristics.

| Lon. Modes | Mode | Eigenvalue | | | Damping Ratio | | | Undamped Frequency (Hz) | | |
|------------|------------------|---------------------|---------------------|---------------------|---------------|-----|-----|-------------------------|-----|-----|
| | | M1 | M2 | M3 | M1 | M2 | M3 | M1 | M2 | M3 |
| | Short Period (I) | -0.0 ± 0.0 <i>i</i> | -0.0 ± 0.0 <i>i</i> | -0.0 ± 0.0 <i>i</i> | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Phugoid (II) | -0.0 ± 0.0 <i>i</i> | -0.0 ± 0.0 <i>i</i> | -0.0 ± 0.0 <i>i</i> | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Lat. Modes | Dutch Roll (III) | -0.0 ± 0.0 <i>i</i> | -0.0 ± 0.0 <i>i</i> | -0.0 ± 0.0 <i>i</i> | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Roll (IV) | -0.0 ± 0.0 <i>i</i> | -0.0 ± 0.0 <i>i</i> | -0.0 ± 0.0 <i>i</i> | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Spiral (V) | -0.0 ± 0.0 <i>i</i> | -0.0 ± 0.0 <i>i</i> | -0.0 ± 0.0 <i>i</i> | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

IV.C.4 Mission Performance

Table 15 Estimated Mission Performance.

| Parameter | Mission 1 | Mission 2 | Mission 3 |
|-------------------------------------|-----------|-----------|-----------|
| Total Weight (lbs) | | | |
| Wing Loading (lbs/ft ²) | | | |
| V_C (ft/s) | | | |
| V_{TO} (ft/s) | | | |
| Payload | | | |
| [YEAR SPECIFIC ITEM] | | | |
| Raw Mission Score | | | |

V Detail Design

V.A Dimensional Parameters

V.B Structural Characteristics and Capabilities

V.C Systems and Sub-system Selection, Integration, and Architecture



Figure Placeholder

Aspect ratio = 4:3

Figure 13 Root-locus plot for stability modes.

Table 16 Dimensional Parameters.

| (a) Main Wing | | (b) Horizontal Tail | | (c) Vertical Tail | |
|-----------------|---------------|---------------------|------------------|-------------------|---------------|
| Parameter | Value (units) | Parameter | Value (units) | Parameter | Value (units) |
| Airfoils | abc | Airfoil | abc | Airfoil | abc |
| Span | 0.0 (ft) | Span | 0.0 (ft) | Span | 0.0 (ft) |
| Root Chord | 0.0 (ft) | Root Chord | 0.0 (ft) | Root Chord | 0.0 (ft) |
| Tip Chord | 0.0 (ft) | Tip Chord | 0.0 (ft) | Tip Chord | 0.0 (ft) |
| Aspect Ratio | 0.0 | Aspect Ratio | 0.0 | Aspect Ratio | 0.0 |
| Dihedral | 0.0 (°) | Volume Ratio | 0.0 | Volume Ratio | 0.0 |
| Incidence Angle | 0.0 (°) | Incidence Angle | 0.0 (°) | Rudder Chord | 0.0 (ft) |
| Flap Chord | 0.0 (ft) | Elevator Chord | 0.0 (ft) | Rudder Span | 0.0 (ft) |
| Flap Span | 0.0 (ft) | Elevator Span | 0.0 (ft) | | |
| Aileron Chord | 0.0 (ft) | | | | |
| Aileron Span | 0.0 (ft) | | | | |
| (d) Fuselage | | (e) Propulsion | | (f) Controls | |
| Parameter | Value (units) | Parameter | Value (units) | Parameter | Value (units) |
| Total Length | 0.0 (ft) | Motor | abc | Transmitter | abc |
| Nose Length | 0.0 (ft) | Kv | 0.0 (RPM/V) | Receiver | abc |
| Tail Length | 0.0 (ft) | Power Rating | 0.0 (W) | Servos | abc |
| Width | 0.0 (ft) | No-Load Current | 0.0 (A) | Flight Controller | abc |
| Height | 0.0 (ft) | Internal Resistance | 0.0 (Ω) | | |
| | | Propeller | abc 0×0 | | |

V.D Weights and Balance

V.E Flight Performance Parameters



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V.F Mission Performance

V.G Drawing Package

The following are drawings including a 3-View drawing with dimensions of all configurations, a structural arrangement drawing, a systems layout/location drawing, and payload accommodation drawings.

Figure Placeholder

Figure Placeholder

Figure Placeholder

Figure Placeholder



Figure Placeholder

Figure 14 V-n diagram for our aircraft design.

Figure Placeholder

Figure 15 Schematic of electrical/avionics systems.

VI Manufacturing Plan

VIA Process Investigation and Selection

Table 20 shows our figures of merit for our manufacturing technique decision matrices. Note that we prioritized in a similar fashion to our design figures with some changes to more applicable figures. First, again, is weight. The lower the aircraft weight, the more points can be had through [YEAR SPECIFIC ITEM]. After weight, we prioritized strength, as our structures need to be able to carry the loads required. Third is simplicity; we need to be able to actually manufacture something with a given technique. Note that simplicity is relative to our team's expertise at the time of our decisions and feasible future abilities within the time frame of the competition. We next chose to include durability. It is not very high on our list since we would hope to be able to design an aircraft that has no unscheduled landings, however, one cannot predict the future enough to know whether or not durability will be required, and experience shows that it most likely will. Finally, [TALK ABOUT THE YEAR SPECIFIC METRIC IF THERE IS ONE.] Because many of these factors depend on intelligent design (e.g. a built-up balsa wing could be heavier than a foam core wing, depending on how it is designed), as well as manufacturer skill, we did some prototyping and testing of representative models before completing our decision factor calculations.



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Table 17 Weight and Balance table including empty aircraft and each possible configuration. Note that the datum point of the aircraft is the center of the leading edge of the main wing.

| | | C.G. Location (ft) | | | |
|---------------------|--------------|--------------------|-----|-----|-----|
| | Component | Weight (lbs) | X | Y | Z |
| Empty Airframe | Fuselage | 0.0 | 0.0 | 0.0 | 0.0 |
| | Wing | 0.0 | 0.0 | 0.0 | 0.0 |
| | H. Tail | 0.0 | 0.0 | 0.0 | 0.0 |
| | V. Tail | 0.0 | 0.0 | 0.0 | 0.0 |
| | Landing Gear | 0.0 | 0.0 | 0.0 | 0.0 |
| | Motor | 0.0 | 0.0 | 0.0 | 0.0 |
| | Total | 0.0 | 0.0 | 0.0 | 0.0 |
| Mission 1 Additions | Component | 0.0 | 0.0 | 0.0 | 0.0 |
| | Component | 0.0 | 0.0 | 0.0 | 0.0 |
| | Component | 0.0 | 0.0 | 0.0 | 0.0 |
| | Total | 0.0 | 0.0 | 0.0 | 0.0 |
| Mission 2 Additions | Component | 0.0 | 0.0 | 0.0 | 0.0 |
| | Component | 0.0 | 0.0 | 0.0 | 0.0 |
| | Component | 0.0 | 0.0 | 0.0 | 0.0 |
| | Total | 0.0 | 0.0 | 0.0 | 0.0 |
| Mission 3 Additions | Component | 0.0 | 0.0 | 0.0 | 0.0 |
| | Component | 0.0 | 0.0 | 0.0 | 0.0 |
| | Total | 0.0 | 0.0 | 0.0 | 0.0 |

Table 18 Expected Flight Performance parameters for each mission.

| Parameter | Mission 1 | Mission 2 | Mission 3 |
|-------------------------------------|-----------|-----------|-----------|
| $C_{L_{\max}}$ | | | |
| $C_{L_{\text{avg}}}$ | | | |
| C_{D_0} | | | |
| L/D_{cruise} | | | |
| efficiency factor (e) | | | |
| V_{TO} | | | |
| V_C | | | |
| Total Weight (lbs) | | | |
| Wing Loading (lbs/ft ²) | | | |
| Takeoff Length (ft) | | | |
| Climb Rate (ft/s) | | | |
| Max Range (ft) | | | |
| Max Endurance (minutes) | | | |

Table 19 Expected Mission Performance.

| Parameter | Mission 1 | Mission 2 | Mission 3 |
|-----------------------------|-----------|-----------|-----------|
| Payload | | | |
| [YEAR SPECIFIC ITEM] | | | |
| Raw Mission Score | | | |



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Table 20 Figures of Merit

| Factor | Relative Importance (1-5) |
|----------------------|---------------------------|
| Weight | 10 |
| Strength | 8 |
| Simplicity | 6 |
| Durability | 4 |
| [YEAR SPECIFIC ITEM] | 2 |

VI.A.1 Wing Manufacturing Process Selection

Table 21 Weighted decision matrix for wing manufacturing technique. Factors here come from our initial testing of balsa and fiber reinforced polymer (FRP) techniques.

| | Foam Core FRP | Hollow Core FRP | Built-up/Balsa | |
|----------------------|---------------|-----------------|----------------|--|
| Factor | Scale | | | |
| Weight | 10 | | | |
| Strength | 8 | | | |
| Simplicity | 6 | | | |
| Durability | 4 | | | |
| [YEAR SPECIFIC ITEM] | 2 | | | |
| Totals | | | | |

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VI.A.2 Empennage Manufacturing Process Selection

Table 22 Weighted decision matrix for tail manufacturing technique.

| | Foam Core FRP | Hollow Core FRP | Built-up/Balsa | |
|----------------------|---------------|-----------------|----------------|--|
| Factor | Scale | | | |
| Weight | 10 | | | |
| Strength | 8 | | | |
| Simplicity | 6 | | | |
| Durability | 4 | | | |
| [YEAR SPECIFIC ITEM] | 2 | | | |
| Totals | | | | |



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VI.A.3 Fuselage Manufacturing Process Selection

Table 23 Weighted decision matrix for fuselage manufacturing technique.

| Factor | Scale | 3D Printing | Hollow Core FRP | Built-up/Balsa |
|----------------------|-------|-------------|-----------------|----------------|
| Weight | 10 | | | |
| Strength | 8 | | | |
| Simplicity | 6 | | | |
| Durability | 4 | | | |
| [YEAR SPECIFIC ITEM] | 2 | | | |
| Totals | | | | |

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VI.A.4 Payload Manufacturing Process Selection

Table 24 Weighted decision matrix for [SPECIFY THIS YEAR'S PAYLOAD DESIGN].

| Factor | Scale | [OPTION] | [OPTION] | [OPTION] |
|----------------------|-------|---|---|---|
| Weight | 10 | <i>Figure Placeholder</i> Aspect ratio = 4:3 | <i>Figure Placeholder</i> Aspect ratio = 4:3 | <i>Figure Placeholder</i> Aspect ratio = 4:3 |
| Strength | 8 | | | |
| Simplicity | 6 | | | |
| Durability | 4 | | | |
| [YEAR SPECIFIC ITEM] | 2 | | | |
| Totals | | | | |

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VI.B Manufacturing Milestones

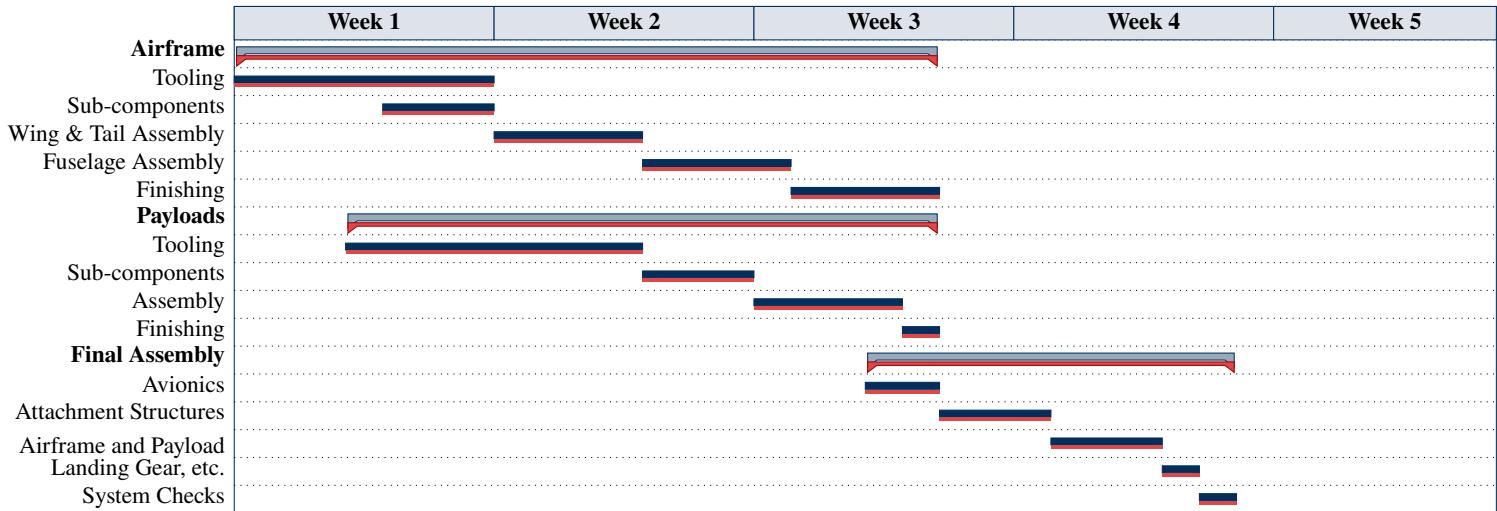
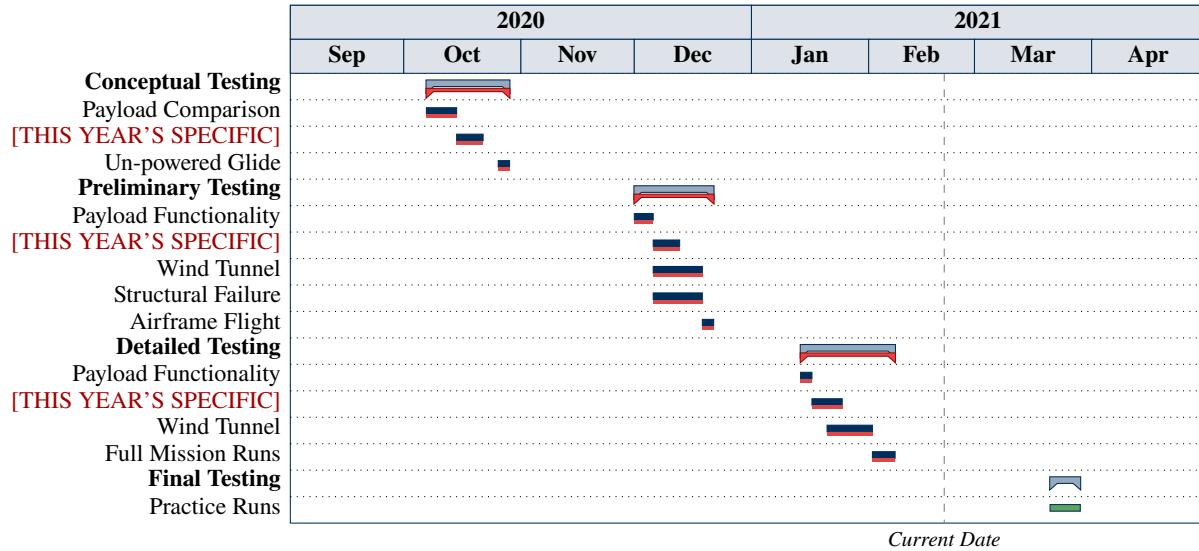


Figure 16 This milestone chart reveals our original plan for major elements of our manufacturing process compared to the actual timing of these events for our detailed prototype, we hope to hold to a similar planned schedule for our competition build.

VII Testing Plan



Current Date

Figure 17 This milestone chart reveals our original plan for major elements of our testing process compared to the actual timing of these events. We anticipate remaining on schedule for the future elements of this chart.

VII.A Completed Testing

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VII.A.1 Ground Testing

Aerodynamic Testing

Structural Testing

Propulsion Testing

Systems Testing Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

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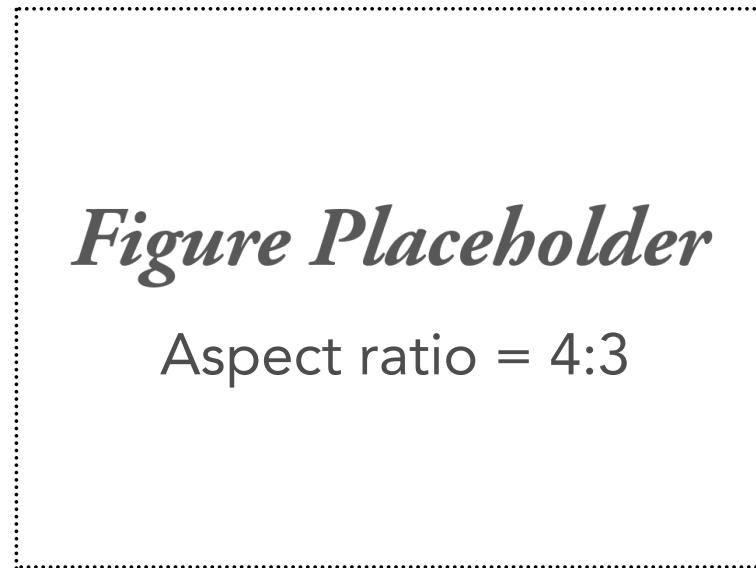


Figure 18 example figure. will need several throughout the testing section

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VII.A.2 Flight Testing

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VII.B Planned Testing

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VII.C Test and Flight Checklists

VIII Performance Results

VIII.A Key Subsystem Demonstrated Performance Comparison

VIII.A.1 Subsystem Improvements After Testing

VIII.B Complete Aircraft Demonstrated Performance Comparison

VIII.C Complete Aircraft Improvements After Flight Testing



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Table 25 Pre-flight Inspection Checklist

| Component | Task |
|-------------|---|
| Propulsion | <input type="checkbox"/> Propeller is balanced and free of visible damage |
| | <input type="checkbox"/> Propeller is securely fastened to motor shaft |
| | <input type="checkbox"/> Motor is free of visible damage and rotates smoothly |
| | <input type="checkbox"/> Motor is securely fastened to airframe |
| | <input type="checkbox"/> Wired connections are undamaged, unexposed, and fit securely |
| | <input type="checkbox"/> Safety fuse/arm switch are undamaged, secured, and fully functional |
| | <input type="checkbox"/> ESC is functional and properly connected |
| | <input type="checkbox"/> Battery is fully charged and properly shaped (not puffy) |
| Fuselage | <input type="checkbox"/> Internal components are secure and fuselage is free of debris |
| | <input type="checkbox"/> Landing gear is securely attached and functional |
| | <input type="checkbox"/> Fuselage is free of damage at all attachment locations |
| | <input type="checkbox"/> All component wiring/connections are correct and secure |
| Wing & Tail | <input type="checkbox"/> Wing and tail surfaces are damage free |
| | <input type="checkbox"/> Control linkages are secure with minimal play |
| | <input type="checkbox"/> Control surfaces are secure and move smoothly and freely |
| | <input type="checkbox"/> Wing and tail are securely mounted to fuselage |
| | <input type="checkbox"/> Wing and tail attachment points are without damage |
| Controls | <input type="checkbox"/> Transmitter arm/disarm switches are functional |
| | <input type="checkbox"/> Receiver and flight controller are connected, secured, and functioning |
| | <input type="checkbox"/> Control surfaces appropriately respond to control inputs |
| | <input type="checkbox"/> Pilot is aware of control mixes and levels |
| | <input type="checkbox"/> Throttle appropriately responds based on arm/disarm settings |

Table 26 Final Flight Test Checklist

| Stage | Task |
|-------------|-------------------------------|
| Pre-flight | <input type="checkbox"/> Task |
| | <input type="checkbox"/> Task |
| Mid-flight | <input type="checkbox"/> Task |
| | <input type="checkbox"/> Task |
| Post-flight | <input type="checkbox"/> Task |
| | <input type="checkbox"/> Task |



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Table 27 Example subsystem performance table.

| Parameter | Mission 1 | | Mission 2 | | Mission 3 | |
|-----------|-----------|----------|-----------|----------|-----------|----------|
| | Expected | Measured | Expected | Measured | Expected | Measured |
| Parameter | | | | | | |
| Parameter | | | | | | |
| Parameter | | | | | | |
| Parameter | | | | | | |

Table 28 Expected Flight Performance parameters for each mission.

| Parameter | Mission 1 | | Mission 2 | | Mission 3 | |
|-------------------------------------|-----------|----------|-----------|----------|-----------|----------|
| | Expected | Measured | Expected | Measured | Expected | Measured |
| $C_{L_{\max}}$ | | | | | | |
| $C_{L_{avg}}$ | | | | | | |
| C_{D_0} | | | | | | |
| L/D_{cruise} | | | | | | |
| efficiency factor (ϵ) | | | | | | |
| V_{TO} | | | | | | |
| V_C | | | | | | |
| Total Weight (lbs) | | | | | | |
| Wing Loading (lbs/ft ²) | | | | | | |
| Takeoff Length (ft) | | | | | | |
| Climb Rate (ft/s) | | | | | | |
| Max Range (ft) | | | | | | |
| Max Endurance (minutes) | | | | | | |
| Payload | | | | | | |
| Score | | | | | | |