Team Flying Tigers Design, Build, Fly Competition

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The overall objective for the 2022-2023 AIAA Design/Build/Fly competition is to successfully develop a remote-controlled aircraft capable of executing electronic warfare missions within the given parameters provided by AIAA. The University of Memphis AIAA DBF team, Flying Tigers, conducted research and analysis to maximize payload and speed in the design of the aircraft for this competition. The runway distance is limited to 60 feet with a maximum battery capacity of 100 Watt-hours. The aircraft and necessary components must fit within a container of 62" length + width +height when packed with a weight of less than 50 pounds. Considering this, the primary limitation is wing area. The payload must make up at least 30% of the overall aircraft weight, thus the aircraft must be designed to be as light as possible with a heavy electronics package. Based on scoring sensitivity testing, the aircraft should have a top speed of 85 mph and a base weight of 4-5 lbs. Accounting for size limitations, the aircraft will be designed to be modular to fit into the required box. From testing, it has been determined that the primary focus of the design is the second mission, which will place the most load onto the aircraft and hinder the flight performance. The third mission, while adding stresses to the wings, will functionally only serve as an additional source of drag and torsional loading. The finalized design will take all testing and parameters into account to maximize points for this competition.

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I. Executive Summary

The overall objective is to successfully develop a remote-controlled aircraft capable of executing electronic warfare missions within the given parameters. To score well in each of the three flight missions, the aircraft must be designed in such a way as to comply with the rules, while maximizing payload and speed. The competition limits the runway distance to 60 feet and a maximum battery capacity of 100 Watt-hours. Considering the rules of the competition, the primary limitation will be wing lift, which will affect both the maximum payload and top speed. Because the payload must make up at least 30% of the overall aircraft weight, it is necessary to design the aircraft to be as light as possible while carrying a relatively heavy electronics package.

The subsequent sections include a summary of the management structure, design approach, manufacturing plan, plan for testing, and beta test results. Based on the scoring sensitivity testing, it has been determined that the aircraft should have a top speed of 85 mph and a base weight of 4-5 lbs. Because of the size limitations in place, the aircraft will be designed to be as modular as possible; fitting within a container that meets the sizing requirements. Testing has concluded that the focus of the design should be the second mission, which will place the most load onto the aircraft and hinder the flight performance greatly. The third mission, while adding stresses to the wings, will functionally only serve as an additional source of drag and torsional loading.

II. Management Summary

The University of Memphis *Flying Tigers* Design / Build / Fly team is made up entirely of members of the university AIAA student branch and advisors. The team consists of six senior members, four underclassmen members, a mechanical engineering faculty advisor, and an alumnus engineering mentor with experience in the model aircraft field. The faculty advisor oversees the AIAA organization, offers project management advice, and interfaces directly with the mechanical engineering department. The team leader oversees and approves all actions including, but not limited to, overall design of the aircraft, team organization, research plans, and project budget. The remainder of the organizational structure consists of a design lead, a propulsion/manufacturing lead, an avionics/mechanisms lead, an aerodynamics lead, and a simulations lead. Major milestones yet to be completed include final design, final assembly, and the Design/Build/Fly (DBF) competition.

III. Conceptual Design

A. Mission Requirements

The aircraft and necessary components must fit within a container of 62” (length + width + height), that must weigh less than 50 lbs when fully packed. Two sets of both left and right wings must be provided, the use of which will be determined by DBF officials on the day of the competition. The aircraft must enter the staging area enclosed in the package and must complete a successful landing for each mission to receive a score. The flight course consists of two 1000 ft straights with a 360° horizontal loop incorporated in the straight opposite the starting point, two turns, and a runway constraint of 60 ft. The aircraft and necessary components must fit within a container of 62” (length + width + height) when packed, and this container must weigh less than 50 lbs.

The DBF competition consists of four missions in which the aircraft’s capabilities will be tested. Mission 1 is the staging flight, where there is a 5-minute flight window, and the highest possible score is 1 for staying in the air for 5 minutes. Mission 2 is the surveillance flight, which includes a 10-minute flight window to complete as many laps as possible within the time constraints while carrying an electronics package weighing no less than 30% of the aircraft’s empty takeoff weight and has dimensions of 3” x 3” x 6”. The aircraft will be weighed upon completion of the 10-minute time window to ensure the package fits within the aforementioned limitations. Scoring will be based off a product of the package weight times the number of laps flown. Mission 3 is a jamming flight, which encompasses a 5-minute flight limit with a single PVC pipe antenna attachment on a single wing, and a completion goal of 3 laps. The scoring is based on the quotient of the length of the antenna divided by the time it takes to complete 3 laps. Mission 4 is a ground mission, where the structural integrity of the plane is tested and incorporates a 10-minute time window. The team must install ground test fixtures onto the sides of the wings, and test weights are applied to the center of the aircraft so that the wings bear the weight. The scoring of this mission is dependent on the total test weight applied divided by the maximum aircraft weight.

B. Scoring Sensitivity Analysis

The scoring sensitivity relies on an objective analysis of how the competition is scored, and how the team can best maximize the final score. Two dependent criteria were determined to achieve the highest possible score: speed and payload. The speed of the aircraft is directly responsible for the scores of missions two and three. Likewise, the payload also contributes equally to the score for the missions; a higher weight and longer antenna will lead to a higher score. Unfortunately, speed and payload conflict with each other, as a heavier aircraft will have higher drag and therefore a lower speed. Similarly, an aircraft that weighs less will produce less lift induced drag and fly faster.

The team determined a single motor to be the ideal, primarily because of the simplicity and cost. A twin motor design would offer better stability in the yaw axis, but manufacturing would be difficult, because each of the four required wings (due to having two identical sets of wings) would have to contain both a motor and Electronic Speed Control (ESC). LiPo batteries are considered the standard for RC aircraft applications, but the team considered other alternatives that offered slight advantages in some regards [6]. Notably, LiFe batteries, while slightly lower power density, are much safer and maintain a stable voltage until fully discharged. This could improve the flight performance of the aircraft, as a stable high voltage would mean a higher RPM. However, LiFe batteries are available at a much higher price point and would not work with the overall budget. The Clark Y airfoil, unlike the two NACA (National Advisory Committee for Aeronautics) profiles, features a flat bottom, and is regularly used in RC aircraft. While NACA 2408 would be slightly lower drag, the decrease in lift counteracts this benefit. NACA 6412, a high lift wing, would be more difficult to manufacture and have more drag.

Although a tricycle landing gear is more functional, the increase in weight, drag, and complexity means that the team would be compromising in multiple areas simply for an easier aircraft to use. Therefore, a tail-dragging skid design was selected. A tail-dragging skid saves weight and produces less drag, improving the power-to-weight ratio. A straight wing was selected, determining that low speed performance to be a primary limiting design feature of the aircraft. At the speeds the aircraft will fly, a swept wing would not be beneficial in the final design. Delta wings create a generous amount of lift but have unfavorable drag characteristics at high angles of attack, which is inherent to their relatively short chord. In addition to this, delta wings would be more difficult to manufacture.

A flying wing aircraft was initially preferred by the team, but it was determined that the complexity would be too great [10]. A conventional wing resolves the issues of a flying wing but will have the smallest wing area. Alternatively, a hybrid design was proposed that would have a fuselage in the shape of an airfoil. While this would effectively double the wing area, the inefficiencies from the very short chord would be detrimental for the performance. Essentially, the large area for wingtip vortices and angle of attack sensitivity creates sources of concern for the design. A conventional tail was selected alongside the conventional wing design, because of its simple design and functionality. A T-tail was not selected because it was determined that the rudder would need to be reinforced to support the elevator.

C. Considered Concepts and Configurations

While brushless motors are generally more expensive, the benefits they possess make them an obvious choice for RC airplanes that fly at the relatively low speeds that will be achieved in competition. Some of the benefits that led to choosing a brushless motor for the final design include the higher power output, high efficiency, low heat output, and considerable durability [1]. Several different types of batteries were considered for this design. However, a lithium polymer battery was chosen as the best battery as it has the highest energy density [2] out of all the other considered batteries mentioned in the appendix. The motor size was based on a desired flight time of 12 minutes for the 2nd mission. It was calculated that the output of a 100 W-h battery, which was a limitation imposed by the competition, with a chosen motor drawing 500 watts will give the 12 minutes of flight time necessary to satisfy the 10-minute time window of the mission plus a 2-minute margin for takeoff and landing, as shown in Eq. (1).

$$\boldsymbol{Power = \frac{Energy}{Time} = \frac{100\,Wh}{\frac{1\,hr}{60\,min} * 12\,min} = 500W} \tag{1}$$

For the mission requirements, a straight wing design is the favorable choice compared to swept and delta wing configurations. Straight wings provide a high lift coefficient at relatively low speeds (20-90 MPH). This allows for shorter takeoff distances and better performance at slow speeds. Additionally, the complexity of a straight wing design is considerably less than that of swept and delta wing configurations. Delta wings and swept wings are effective at high speeds; however, at low subsonic speeds their benefits are diminished. Delta wings induce more drag at high angles of attack as compared to other wing configurations, which reduces the retained energy of the aircraft during maneuvers. Similarly, swept wings induce less drag at a higher speed, but straight wings have more wing area in comparison, which results in better performance at lower speeds.

There are two main types of RC aircraft landing gears: tricycle and tail-dragger. Considering the mission requirements, a tail-dragging landing gear is an optimal choice; it saves weight and produces less drag. A tricycle landing gear is a safer design: two main wheels at the center of the aircraft with a smaller third wheel in front. They are generally easier to taxi and less likely to flip over upon takeoff and landing. Also, the reduction in structural components associated with a tail skid saves weight on the aircraft and reduces drag – two important characteristics as they relate to the mission requirements. The specific design features a plywood tail skid attached. Generally, in low wind conditions, a tail dragger system operates normally upon takeoff and landing. However, steering is impacted, and in high wind conditions they can be more difficult to control during takeoff and landing. The figure below analyzes the stabilizing versus destabilizing moment of a tricycle vs tail-dragging landing gear. These complications are negligible when the positive impact can be seen in the mission score.

IV. Preliminary Design

A. Design and Analysis Methodology

The methodology used for the preliminary design was based on designing in a way that maximizes points under the missions and constraints given by the DBF rules, while also remaining within budget. The team developed several sensitivity analyses over the course of the design part of the project to determine the optimal parameters of the RC plane. The following paragraph outlines considered parameters.

The aircraft was designed to be light enough to meet the guidelines that the payload must be at least 30% of estimated takeoff weight. The payload weight was also considered in the way that the fuselage was optimized to carry the large payload. For the wing and wing support, items that were considered were the antenna, counterweight for the antenna, and the torsion created from the weight. The antenna had to be able to be securely fitted to the plane and the counterweight was necessary for the stability of the flight. However, this makes the wings heavier and the support, in turn, must be able to accommodate this. Points are also awarded for speed, so speed was optimized in the methodology used. Thus, the design must be more aerodynamic. The plane was also restricted to be able to fit within the shipping box and on the test stand at the competition.

B. Trade-offs in Design and Sizing

The team had to make difficult decisions concerning the design and sizing of the aircraft. Trade-offs had to be made to meet specifications and stay within budget. The fuselage had to be cut in half to fit within the shipping box, and the wing size had to be reduced for the same reason. Battery limitations as provided in the AIAA DBF rules significantly reduced the motor output, so the aircraft would not reach the speed that was initially intended. However, the team agreed that the most important reason for trade-offs was due to cost limitations. A large cost limitation was the materials that are accessible and usable. An example of this is carbon fiber for 3D printing: carbon fiber is very costly, so the wings of the aircraft could not be made from 3D printed carbon fiber. The team was also unable to produce as many model variants as desired to test due to the budget.

C. Methodology for Prediction of Aircraft Performance

The team was able to estimate the mission scores of the aircraft through testing computationally and experimentally and using researched values to see how the chosen design elements, such as tail drag landing gear, operate in the given environment. Computational simulations were used to determine drag with different airfoils using MATLAB. Excel and eCalc were also used to produce computational results with lift and drag equations. Experimental examples of this estimation included wind-tunnel testing of the airfoil design, and a practice RC plane with a similar motor and size to the actual plane to see speed and durability. The team also included a payload in the fuselage. Using both methods, the team could estimate how the aircraft would perform.

Prediction of the aircraft performance also lies heavily in the terrain and weather of the flying field. In Figure 1 below, the home flying field in Memphis, TN, is compared with the flying field in Tucson, AZ, including some climate related uncertainties. These are the climate zone, temperature, wind average, wind gusts, terrain, and elevation. Additional risks identified include damage during shipping, strain due to testing, and unidentical wing sets. All of these could cause potential failure or issues in flight.

Uncertainty	Memphis, Tennessee	Tucson, Arizona
Climate Zone	Humid Subtropical (Zone 7b-8a)	Hot Semi-Arid (Zone 9a)
Daytime Temperature (April 2022)	66-81 °F	72-88 °F
High Wind Average (April 2022)	10 mph	8.7 mph
Wind Gusts	Very gusty	Light gusts
Terrain	Mostly flat	Desert, hills
Elevation	337 feet	2,398 feet

Fig. 1 Climate in Memphis, TN vs. Tucson, AZ

D. Estimates of the Aircraft Performance

At the competition altitude of approximately 2,400 feet, the aircraft will produce less lift at a given airspeed. This means that the aircraft will be forced to reach a higher airspeed to take off within the 60-foot runway. It is to be assumed that the takeoff speed will be slightly higher than the stall speed, which was found using eCalc to be approximately 20 mph. With the altitude factors in mind, a thrust-to-weight ratio of 0.75:1 is a minimum for the design to be viable. Using a 500W motor and various propeller diameter and pitch combinations, the team finds the limitation for top speed to be around 85 mph. While it is possible to create a motor and propeller combination that can achieve this goal, the team determined that a top speed of 75 mph would serve as a compromise, giving a relatively high speed and thrust-to-weight ratio, as shown in Fig. 2 below.

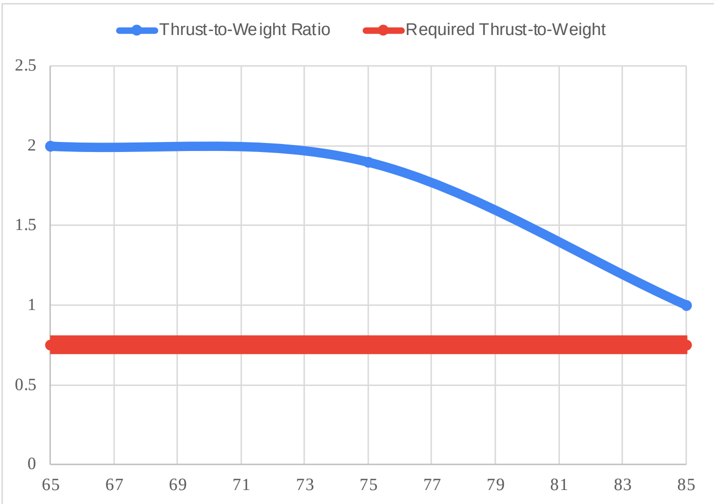

Fig. 2 Thrust-to-Weight Ratio with 500W Motor

V. Detail Design

A. Dimensional Parameters of the Final Design

Because the requirement is 62” L+W+H, the team decided to use 30 x 17 x 15” for the box. The aircraft has wingspan of 58” and length of 50”. Because of the box limitations, an elevator with a width of 16” and a rudder + skid 12” tall was necessary. Despite this, the elevator is appropriately sized, according to Trainer Designer. To accommodate the 3 x 3 x 6” package, the aircraft fuselage is 3.5” wide, with a height of 4.5”. To fit the wing inside the package and meet the competition guidelines, it is split in the middle.

B. Structural Characteristics and Capabilities of the Final Design

Because the wing is meant to be split in half, a spar joiner was designed to hold the two halves together, while providing torsional strength. Using a plywood spar joiner, flanked by two carbon fiber rods, the wings are held together by friction and screws. The rectangular spar joiner acts as an extension of the normal wing spar but is not connected to the lower web of the I-beam on either side. This was determined to be an acceptable tradeoff, as this portion of the wing does not experience a great deal of stress. The carbon fiber spar joiner is used to join the secondary spars, which serve to prevent rotation of the wing sections and hold them together. Carbon fiber was chosen due to its high tensile strength, resistance to deformation, and light weight. The main spar for the aircraft is an I-beam with a balsa web and basswood flanges. Because the web does not encounter as much stress as the flanges, it can be made of lighter material, such as balsa. To improve the strength of the ribs, the spar webs are cut between each gap. The shear and moment calculations for the wing spar based on a 5 lb. airplane weight distributed over a 58" beam and a 2.5 lb. point load at mid-span are shown in Fig. 3 and Fig. 4 below.

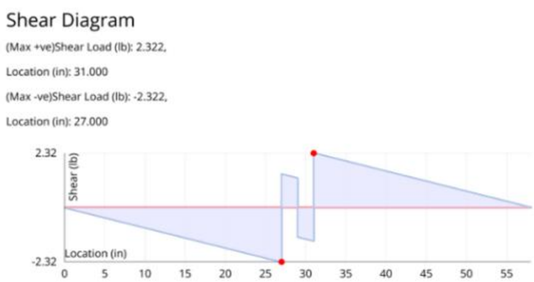

Fig. 3 Wing Spar Shear Diagram

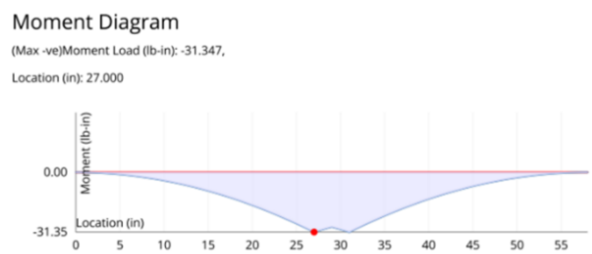

Fig. 4 Wing Spar Moment Diagram

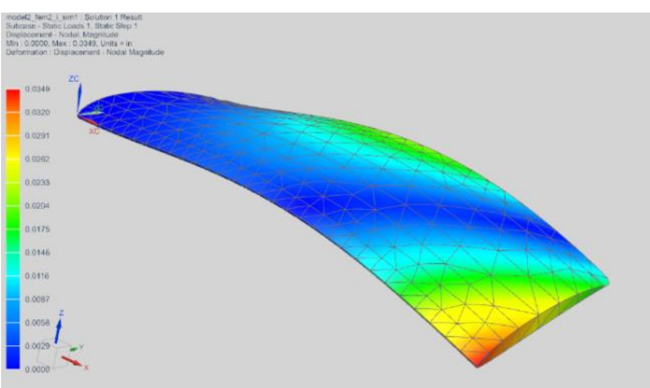

Fig. 5 Wing Displacement FEA

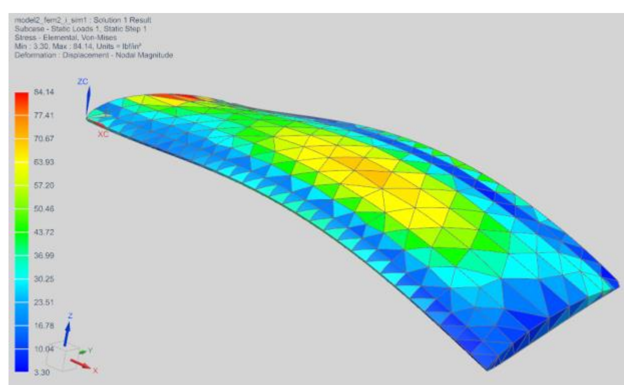

Fig. 6 Wing Von Mises Stress FEA

To get a better understanding of the stresses and deformation that will take place with the wings at max loading, finite element analysis (FEA) is done using Siemens NX. The cross section of the wing is taken and extended to half the length of the total wingspan. From this, the predicted load of the PVC pipe is used and a calculated air resistance force with the known mechanical properties of balsa wood to find the deformation and stress. The mechanical properties used for the model are density, 130 pounds per cubic inch, and the modulus of elasticity, at 538 kpsi. The displacement diagram is shown in Fig. 5 and the Von Mises stress diagram is shown in Fig. 6.

VI. Manufacturing Plan

The manufacturing plan has several steps to advance from an initial design to a final product. The plan begins with a preliminary design, using small-scale model analysis to test different aspects of the plane according to the scoring rubric. This data was used to create a final optimized design. The manufacturing process is parallelized with testing, as this is iterative and requires exchanging design components based on results from collected data. Siemens NX computer-aided design (CAD) software will be used to model these iterative designs.

After the finalized design, the final materials for the plane were chosen and ordered. Material testing helped to decide the final materials and design changes. Preliminary design analysis suggests using carbon fiber spars and balsa wood ribs to meet design constraints, which is what was chosen for the final design. The assembled wings are wrapped in Monokote to ensure a low-drag airfoil. A Computerized Numerical Control (CNC) machine is used to manufacture precise, identical pieces of the aircraft like the ones shown in the flat patterns of Fig. 7 and Fig. 8.

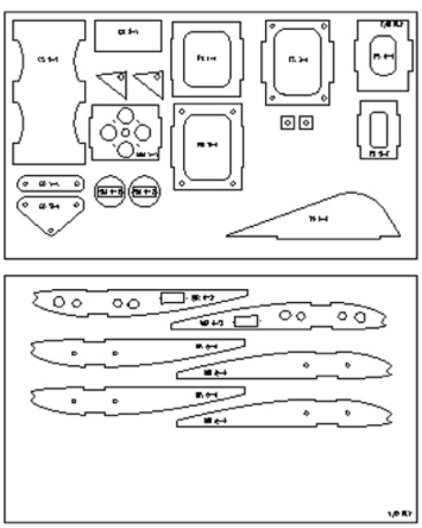

Fig. 7 Plywood Components For CNC

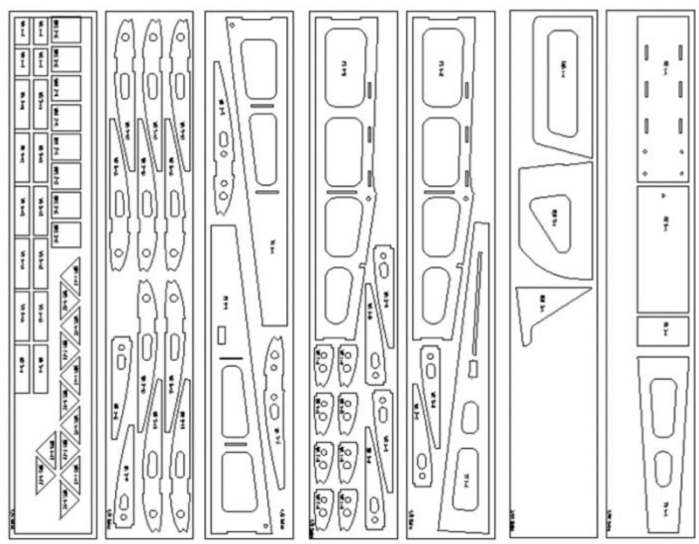

Fig. 8 Balsa Wood Components For CNC

VII. Testing Plan

The flight test plan will consist of an inspection of the aircraft to determine its airworthiness and ability to complete mission requirements. This will also verify that the systems of the aircraft, both physical and electronic, are functioning nominally. The amount of time it takes to unpack, assemble, and set up the aircraft to ensure readiness for competition day will also be measured. The structural, power system, and ground tests will be completed prior to the maiden flight of the aircraft. The aerodynamics and flight tests will be conducted sequentially in multiple flights. A wind tunnel will be used to analyze the variations in lift and drag for several Clark Y airfoil iterations. The load bearing capabilities of the wing will be used to determine which airfoil is acceptable. The testing is intended to be as thorough as possible, accounting for any potential sources of failure prior to their occurrence.

During testing, the top speed, as well as landing and stalling will be measured and documented. The ground testing will be very similar to the ground mission: weights will be added to the wings and the structural integrity will be observed. The schedule for testing will go as follows: first will be electronics control, remote response time, and fail safes; second will be speed; third will be stability and maneuverability; and last will be the ground mission testing. The goal for the first test will be the fastest response times and dependable fail safes. For the second test, the goal will be reaching a speed as close to the top estimate as possible. For the third, the goal is to have the aircraft be able to maneuver easily and fly with a high degree of stability with minimal vibration. The final goal is to add as much weight to the wings as possible before reaching failure. This can be tested using a sample spar and spar joint section to save material as opposed to testing the full wing.

For speed, a distance and time measurement and a GPS module will be used to attain a top speed measurement. This data will be used to compare estimated speed and adapt the aircraft to be more aerodynamic. The time for the electronic system response will be measured and used to adapt the avionics system if necessary. The data for maneuverability and stability will be entirely qualitative; the aircraft will perform several maneuvers to observe how the aircraft behaves. For the ground mission, the data collected will be both qualitative and quantitative: for each amount of weight, the weight will be documented, and the wings will be observed to determine if they are close to failure via deflection. A representation of what the final design airframe will look like in flight for Mission 1 and 2 is shown in Fig. 9.

Fig. 9 CAD Representation of Aircraft in Flight, Without Skin Covering

Appendix

A1. Motor Decision Matrix

Motor

	Ease of Fabrication	Payload Capacity	Safety	Weight	Speed	Flight Stability	Weighted Score
Sensitivity	5	4	5	4	3	3	—
Single	5	—	5	5	5	3	94
Twin	3	—	3	3	5	5	72

A2. Battery Decision Matrix

Battery

	Ease of Fabrication	Payload Capacity	Safety	Weight	Speed	Flight Stability	Weighted Score
Sensitivity	5	4	5	4	3	3	—
LiPo	—	—	1	5	—	—	25
Li-Ion	—	—	2	3	—	—	22
NiCad	—	—	4	1	—	—	24
LiFe	—	—	3	2	—	—	23
NiMh	—	—	4	1	—	—	24

A3. Airfoil Decision Matrix

Airfoil

	Ease of Fabrication	Payload Capacity	Safety	Weight	Speed	Flight Stability	Weighted Score
Sensitivity	5	4	5	4	3	3	—
Clark Y	5	3	—	—	3	5	61
NACA 2408	3	2	—	—	4	4	47
NACA 6412	3	5	—	—	2	3	50

A4. Landing Gear Decision Matrix

Landing Gear

	Ease of Fabrication	Payload Capacity	Safety	Weight	Speed	Flight Stability	Weighted Score
Sensitivity	5	4	5	4	3	3	—
Tail Drag	4	—	3	4	4	3	72
Tricycle	3	—	4	3	3	4	68

A5. Wing Design Decision Matrix

Wing Design

	Ease of Fabrication	Payload Capacity	Safety	Weight	Speed	Flight Stability	Weighted Score
Sensitivity	5	4	5	4	3	3	—
Straight	4	5	—	—	2	3	55
Swept	2	3	—	—	5	3	46
Delta	3	4	—	—	3	4	52

A6. Wing Configuration Decision Matrix

Wing Configuration

	Ease of Fabrication	Payload Capacity	Safety	Weight	Speed	Flight Stability	Weighted Score
Sensitivity	5	4	5	4	3	3	—
Conventional	5	2	—	—	5	5	48
Hybrid	4	3	—	—	3	4	42
Flying Wing	2	4	—	—	2	3	38

A7. Tail Configuration Decision Matrix

Tail Configuration

	Ease of Fabrication	Payload Capacity	Safety	Weight	Speed	Flight Stability	Weighted Score
Sensitivity	5	4	5	4	3	3	—
V Tail	5	—	—	3	4	2	55
T Tail	2	—	—	2	3	5	42
Conventional Tail	4	—	—	3	3	5	56

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References

[1] McGrady, C., Electronics, A., & Chris McGrady is a veteran of the DIY. (2022, October 13). *Brushless vs brushed motor: Best DC motor for your project*. Arrow.com. Retrieved February 23, 2023, from https://www.arrow.com/en/research-and-events/articles/which-dc-motor-is-best-for-your-application

[2] Tim. (2022, April 5). NiMH vs. Lipo RC Car Batteries. Clutch RC. Retrieved February 24, 2023, from https://clutchrc.com/nimh-vs-lipo-batteries/#:~:text=LiPo%20batteries%20are%20a%20newer,source%20choice%20for%20RC%20enthusiasts

[3] Keith Araujo - Epec, L. L. C. (n.d.). *Battery Cell Comparison*. Epec Engineered Technologies - Build to Print Electronics. Retrieved February 23, 2023, from https://www.epectec.com/batteries/cell-comparison.html

[4] Dunbar, B. (2015, August 13). NASA Armstrong Fact Sheet: Eclipse Tow Launch Demonstration Project. NASA. Retrieved February 23, 2023, from https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-049-DFRC.html

[5] Scott, J. (n.d.). Aircraft Landing Gear Layouts. Aerospaceweb.org | Ask Us - Aircraft Landing Gear Layouts. Retrieved February 23, 2023, from https://aerospaceweb.org/question/design/q0200.shtml

[6] Mazz. (2021, February 24). Clark Y airfoil Pros and Cons. Thoracentesis. Retrieved February 23, 2023, from http://www.thoracentesis.science/2021/02/Clark-Y-airfoil%20.html

[7] Sherwin, L., & Naweed, A. (n.d.). 'little wake turbulence, huh?' applying a contemporary model of learning and memory to the American Airlines Flight AA587 accident. Taylor & Francis. Retrieved February 24, 2023, from https://www.tandfonline.com/doi/abs/10.1080/1463922X.2016.1236156?journalCode=ttie20

[8] Hainline, K., Richter, J., & Agarwal, R. (n.d.). Vehicle Design Study of a straight flying-wing with Bell shaped ... Aerospace Research Central. Retrieved February 24, 2023, from https://arc.aiaa.org/doi/abs/10.2514/6.2020-0007