UNIVERSITY OF CALIFORNIA, SAN DIEGO

2018-2019 AIAA Design/Build/Fly Competition

Design Report

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1.0 Executive Summary

The objective of the 2018-2019 American Institute of Aeronautics and Astronautics (AIAA) Design/Build/Fly (DBF) competition this year is to design and manufacture a multi-purpose aircraft to support carrier operations [2]. This plane was created with the purpose of completing three flight missions and one ground mission successfully. The three flight missions consist of one unloaded demonstration flight, one loaded flight with radome, and one loaded flight with attack stores.

1.1 Design Process

The main objective of the team is to place during competition. To accomplish this, the team underwent a design process that tested multiple plane configurations in order to maximize flight score. Through identifying and weighing criterion and the manufacture of lower quality prototypes, the team was able to determine the optimal design off the initial conceptual designs. Additionally, the team was able to determine the appropriate propeller, motor, and battery configuration for both the conceptual design and the competition requirements. Lift, drag, and weight analyses were performed to achieve the optimal score. The final design consists of a fast, lightweight conventional aircraft which can carry the radome or six attack stores. The team believes this is the optimal design as analyses and trade studies indicate that at anticipated peak velocity, six attack stores is the maximum that may be dropped within a ten-minute span producing the highest score.

1.2 Key Mission Requirements

The challenges posed in the 2018-2019 DBF competition consists of three flight missions and one ground mission. Mission 1 consists of an unloaded flight wherein a passing score is awarded if three laps are completed within a five-minute window. Mission 2 is a flight with the rotating radome as payload where score is determined by the aircraft speed relative to the fastest team's aircraft speed. Mission 3 is a payload flight with attack stores beneath the wings. Scoring for Mission 3 is determined by the number of laps where an individual attack store is dropped. The Ground Mission requires quick installation and removal of the radome and attack stores with scoring dependent on the speed at which this is accomplished relative to the fastest team's score. Additional requirements include the aircraft rolling through a 3ftx2ft box unimpeded with the aft landing gear being no further than 2ft from the foremost part of the aircraft [2]. Through these requirements, the team determined the following design elements that should be optimized in order to maximize scoring.

- Aircraft Speed: The aircraft speed at minimum must be, at minimum, high enough to complete three laps within five minutes as required by Missions 1 and 2. Additionally, Mission 2 scoring is directly dependent on aircraft speed relative to the speeds of competing teams' aircraft with a greater speed resulting in a higher score. Finally, a greater number of attack stores may be dropped during Mission 3 if accompanied by a high aircraft speed.

- Maximize Attack Stores: Based on the scoring formulas, the number of dropped attack stores is highly emphasized. As such, the team determined the design must allow for the maximum number of attack stores that may reasonably be dropped within a ten-minute span.

1.3 Final Capabilities

A full test flight has yet to be completed, therefore the final capabilities are not fully known to team yet. So far, static tests have revealed that subsystems have reasonable accomplishment of their final goals. Based off our design, the plane will have the following capabilities:

- Carry 6 attack stores (complete 6 scoring laps during Mission 3)
- Top speed of 70 ft/sec
- Take off within 10 feet

The remainder of this report will provide details into the design process implemented for the 2018-2019 competition season as well as the plans for continued development prior to the competition in April 2019.

2.0: Management Summary

The 2018 - 2019 UCSD DBF team is comprised of 13 members. 4 members are graduating seniors and 9 members are juniors, sophomores, and freshmen. Section 2 outlines the organizational structure of the team during the 2018 - 2019 competition season.

2.1: Team Organization Overview

UCSD DBF implemented a hierarchical management and delegation structure for the 2018 - 2019 competition system. Two project managers were elected at the end of Spring quarter in 2018 to lead the team. One project manager was tasked with overseeing funding, supply logistics, the design report, and competition travel. Another project manager was responsible for overseeing the design, fabrication, and assembly of the competition plane. There are 7 subteams corresponding to these responsibilities: structures, propulsions, controls, aerodynamics, fabrication, report, and finance/outreach. Each subteam has an elected lead member who is responsible for completing the tasks delegated to their subteam by the project managers. ***Figure 2.1*** outlines the hierarchical management structure followed by the team, and ***Figure 2.2*** details what tasks are delegated to each subteam. Finally, general members are able to join any subteam and encouraged to explore as many as they would like, building skills across disciplines. General members were asked at the end of Fall quarter to commit primarily to 1 subteam to build expertise and ensure that all project goals were being accomplished in a timely manner.

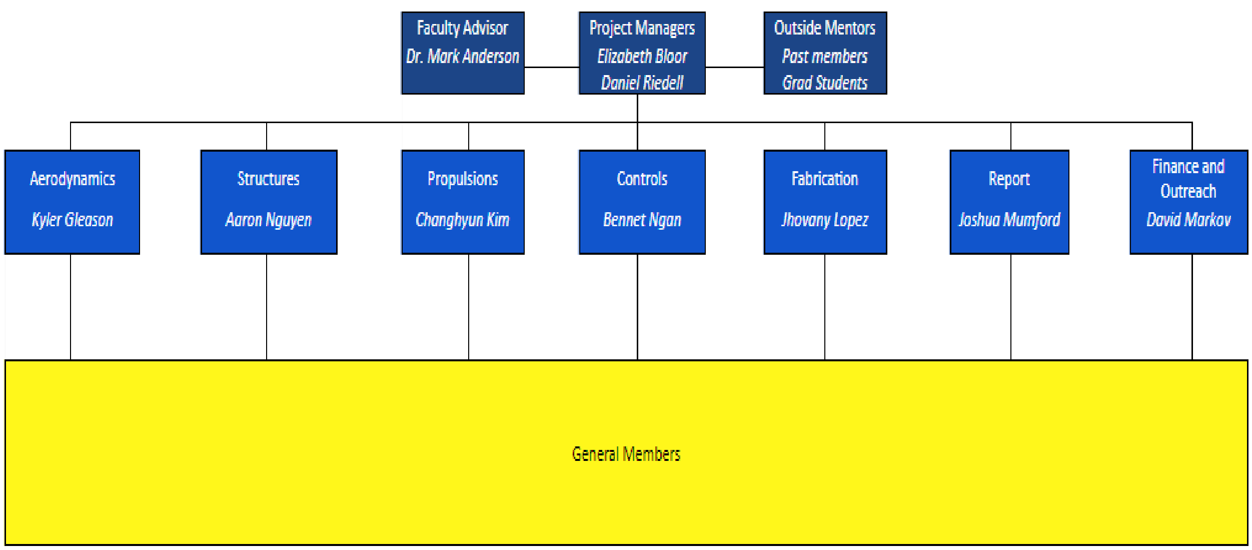


Figure 2.1: Team Hierarchy

2.1 Cont':

Subteam	Responsibilities
Aerodynamics	Airfoil Selection, Wing Sizing, Control Surface Design, Drag Minimization Strategies
Structures	Structural Analysis, Fuselage Design, Landing Gear Design
Propulsions	Motor Selection, Battery Sizing,
Controls	Flight Controller Selection, Servo Selection, Radome rotation, Attack Store Drops
Fabrication	Plane Component Fabrication, Assembly, Defining Manufacturing Limitations
Report	Proposal, Report, Record Keeping, Rules Communication
Finance/Outreach	Securing Funding, Building Industry Relations, Coordinating Outrach/Team Activities

Figure 2.2: Subteam Responsibilities

2.2: Project Timeline

The team has developed a Gantt chart project timeline to track the progress for design, manufacturing, and testing of this year's aircraft. This chart is outlined by ***Figure 2.3***. The highlighted sections show which weeks an item of the project is scheduled to take place. Weeks where milestones occur are highlighted in purple. These milestones represent the deadline for an objective to be completed. The weeks highlighted in red represent overshoots due to unexpected circumstances.

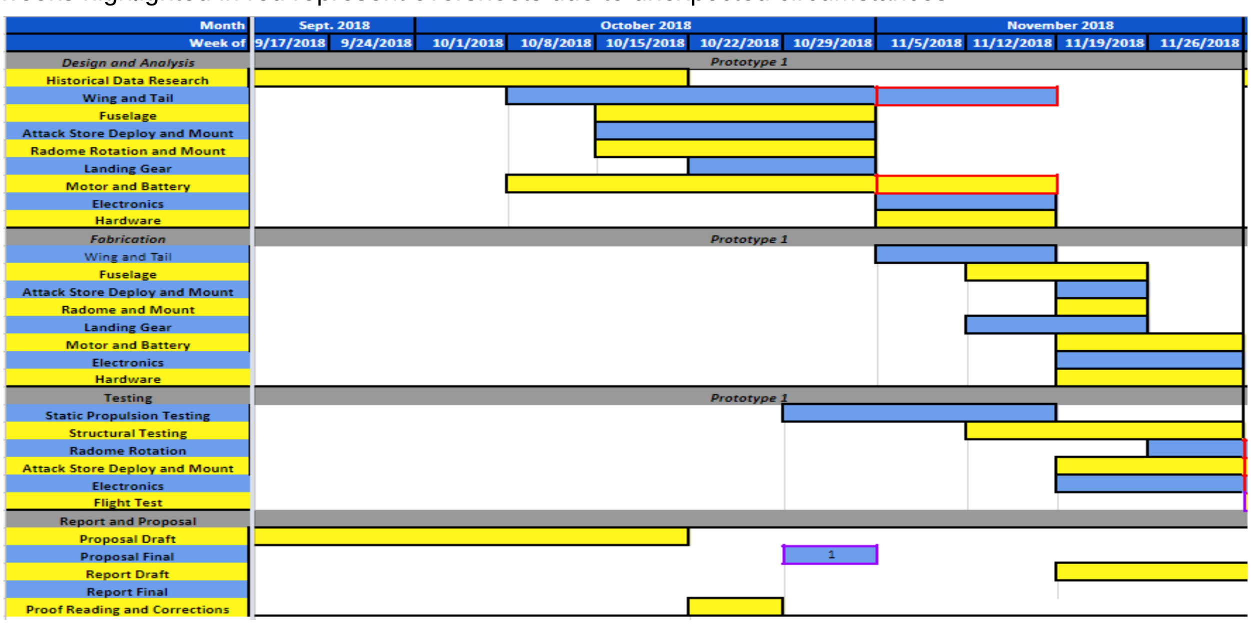


Figure 2.3: Gantt Chart of Project Schedule

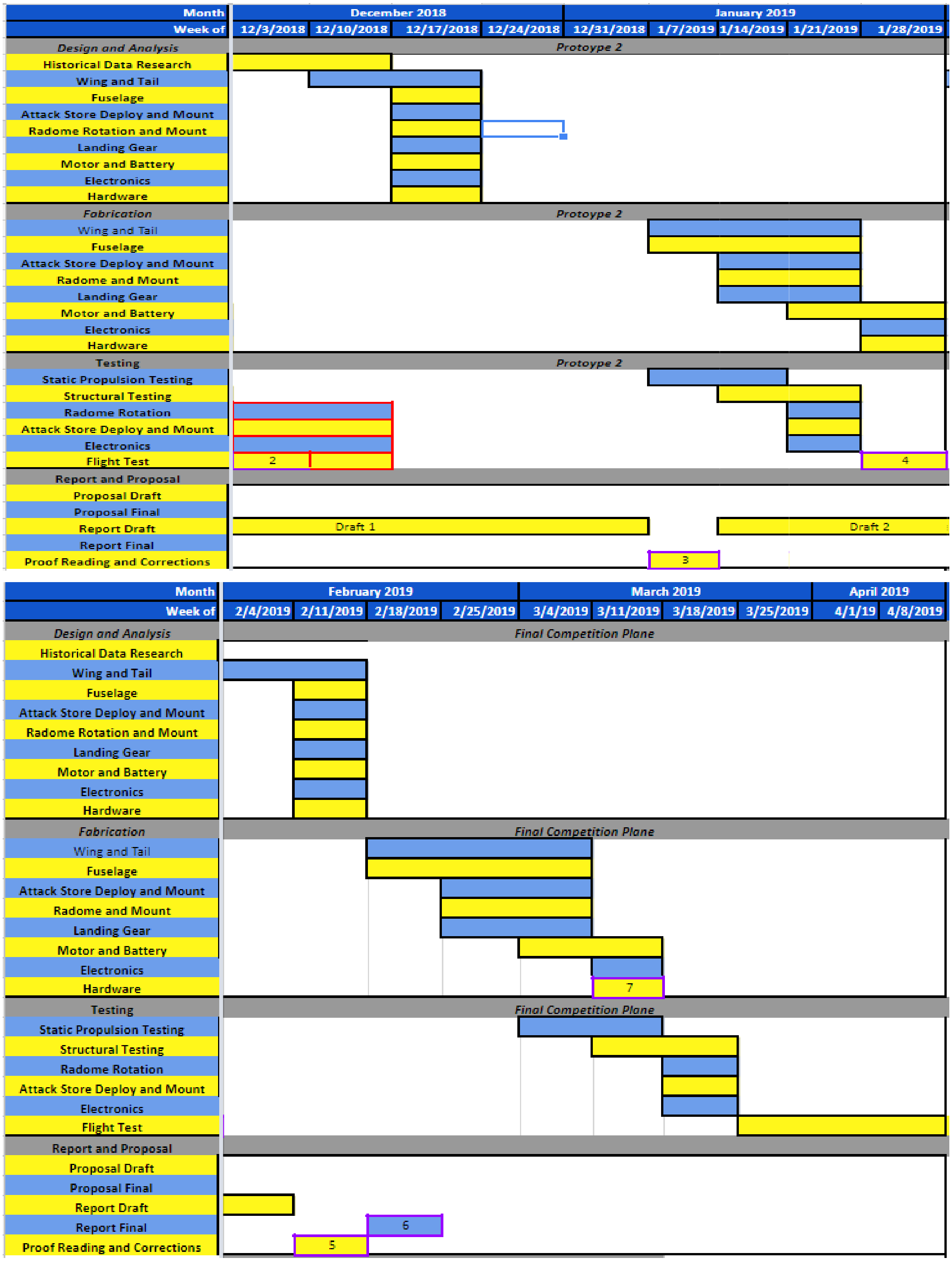


Figure 2.3: Gantt Chart of Project Schedule

3.0: Conceptual Design

3.1: 2019 Competition Overview - Mission Summary and Scoring:

The 2019 DBF competition simulates the design of a multi-purpose aircraft with the capacity to perform aircraft carrier operations. Aircraft will complete three flight missions to test performance for delivery, reconnaissance capability, and attack capability. The delivery capability of the aircraft is demonstrated through Mission 1, which is an empty-weight demonstration flight that also checks the ability of the aircraft to remotely transition from stowed to flight configuration. The reconnaissance capability of the aircraft is demonstrated in Mission 2 in which the aircraft must take on a rotating radome payload and in which scoring is dependent on the speed in which the aircraft can complete 3 laps within a 5-minute flight window. The attack capability of the aircraft is demonstrated in mission 3 in which the aircraft must be outfitted with at least 4 attack stores and in which scoring is dependent on how many "scoring laps" are completed within a 10-minute flight window. Additionally, the aircraft must complete a ground mission at any time up to two times in which assembly crew members must install and test the rotating radome then attack stores subsequently within a 5-minute staging window and in which scoring is dependent on how fast these payloads are installed onto the aircraft. This requirement simulates operations and maintenance that would be conducted on an aircraft while on a carrier flight deck. An aircraft that accomplished the goals of each mission should score well in the competition. All flight missions follow the lap format outlined in ***Figure 3.1*** [2]. This lap is comprised of two 1000 ft straight paths connected with two 180° turns and a 360° turn in the middle of the second straight path. To complete a flight successfully, aircraft must depart from the starting line, take off within 150 ft of the starting line, and land intact and crossing the starting line.

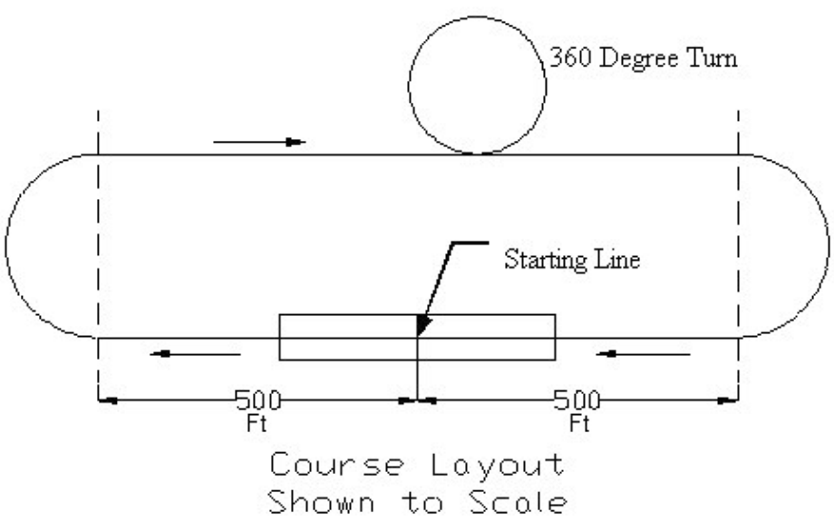


Figure 3.1: AIAA Competition Lap Layout

Mission 1:

Mission 1 demonstrates the capabilities of the aircraft to fly. The aircraft must be able to fly empty for 3 laps within 5 minutes to complete this mission. Additionally, the aircraft must enter the staging box in a stowed configuration and transition to flight configuration remotely before the flight begins. Successful completion of first mission gains teams 1 point and allows them to advance to mission 2 [2].

M1 = 1 (for successful attempt)

Ground Mission:

During the ground mission, a team assembly crew member and pilot must install, test, and remove a rotating radome and four attack stores on the aircraft subsequently. The mission is split between two stages. The first stage involves the installation of the radome by an assembly crew member and the remote activation of the radome by the pilot. The second stage involves the removal of the radome and installation of the 4 attack stores followed by the arming of the aircraft, demonstration of flight controls and propulsion by the pilot, disarming of the aircraft by the crew member, and finally demonstration that each store can be released one at a time. The installation portions of both stages are timed, summed, and are used for the basis of scoring (N_time or tN) against the fastest minimum time of the whole competition (Min_time or tMin) [2].

GM = [Min_time / N_time]

Mission 2:

Mission 2 is a reconnaissance mission with a rotating radome payload. Five minutes will be given to complete three laps, however, a shorter time to complete the three laps will add to the score for this mission. The scoring breakdown for Mission 2 grants at least half of the mission's score for successful completion of the mission and additional score based on the speed achieved completing the mission by the team (N_time or tN) compared to the fastest speed achieved completing the mission in the whole competition (Min_time or tMin) [2].

M2 = 1 + [Min_time / N_time]

Mission 3:

Mission 3 is an attack mission with a payload of at least 4 attack stores. The scoring breakdown for Mission 3 grants 2 points for the mission's completion and an additional point for every successful "scoring lap" completed during the mission. A scoring lap constitutes the successful remote drop of 1 and only 1 attack store on the downwind leg of the flight pattern. Ten minutes will be given to complete as many scoring laps as possible [2].

M3 = 2 + number of scoring laps

Total Score:

The total score (Ts) is a function of the sum of each mission score and the team's report score (Rs) [2].

$$Ts = Rs * (M1 + M2 + M3 + GM)$$

3.2: Design Requirements and Objectives:

Based off of the mission requirements, scoring, and general requirements, the team generated a set of design requirements and objectives which were used in the selection of a final design concept. The mission design objectives that were translated from the mission requirements are outlines in ***Figure 3.2***. Additionally, the team also took the competition's general requirements into account when considering design concepts. These restraints and objectives enabled the team to produce Figures of Merit, which were used to select the conceptual design for the aircraft. Many of these requirements are due to AMA restrictions, while some are competition specified requirements [2].

General Design Restraints:

Propulsion:

- Aircraft must be electric motor and propeller driven
- All propellers used must be commercially produced
- All motors used must be commercially produced

Power Supply:

- Sole power supply for flight must come from on-board batteries
- No externally assisted take-off power provided
- Batteries must be commercially produced Nickel Cadmium (NiCad) or Nickel Metal Hydride (NiMH) with proper insulation via shrink wrap, and with visible labels on cells documenting the manufacturer

Size and Configuration:

- Total weight must be less than 55lbs
- No lighter-than-air configuration may be used to provide lift
- No rotary wing configuration may be used to generate lift
- No structural components may be dropped mid flight
- Radome
  - 12in diameter
  - Mounted on aircraft centerline
  - 3in clearance from rest aircraft

- Attack Stores
  - Capable of carrying ≥ 4 attack stores
  - First 4 mounted under wings
  - Capable of remote individual detachment
  - Minimum clearance of 0.5in
- Minimum wingspan of 4ft
- Wings must fold to roll through 3ft x 2ft x 2ft box
- Nose and all landing gear must fit within the box

Score Factor	Objective	Crucial Design Parameters
Mission 1	Complete three laps in five minutes or less	Empty Weight (W_e) Motor Power (P_m) Lift (F_L)
Mission 2	Complete three laps with the radome installed as fast as possible	Radome Drag (D_R) Weight of Radome (W_R) Motor Power (P_m)
Mission 3	Complete as many laps as possible with a payload of at least 4 attack stores	Total Weight (W_{tot}) Attack Store Weight (W_A) Attack Store Drag (D_A) Motor Power (P_m) Power Supply (B)
Ground Mission	Deploy the plane and attach radome and attack stores as fast as possible.	Radome attachment speed Attack store attachment speed

Figure 3.2: Table of Mission Objectives and Design Parameters Affected

Score Sensitivity Analysis:

The team analyzed the objectives of each score factor found in ***Figure 3.2*** to identify design parameters for further investigation that would be prioritized in the design decisions. Because of the time requirements of Missions 1 and 2 top speed and weight were determined to be the most central parameters. This is because the two are largely interrelated. Additionally, the added weight of the radome and attack stores affect scores of Missions 2 and 3, as the weight of the radome and attack stores ultimately impacts stability and speed during these flights. Therefore, two analyses were performed based on previous data to obtain design requirements for speed and weight of the aircraft. This ultimately determined how many attack stores were pursued.

Speed Targeting:

Based on historic data from the 2017 Design/Build/Fly competition in Tucson, the speed to final score relationship was analyzed using the scores from Mission 2 which was a speed run. The maximum speeds of the top 50 teams were placed into 10 brackets and their average final competition score. This relationship was used to select a target speed for the aircraft this year [7]. ***Figure 3.3*** shows this relationship. The target speed was chosen to be 70 ft/s from this analysis.

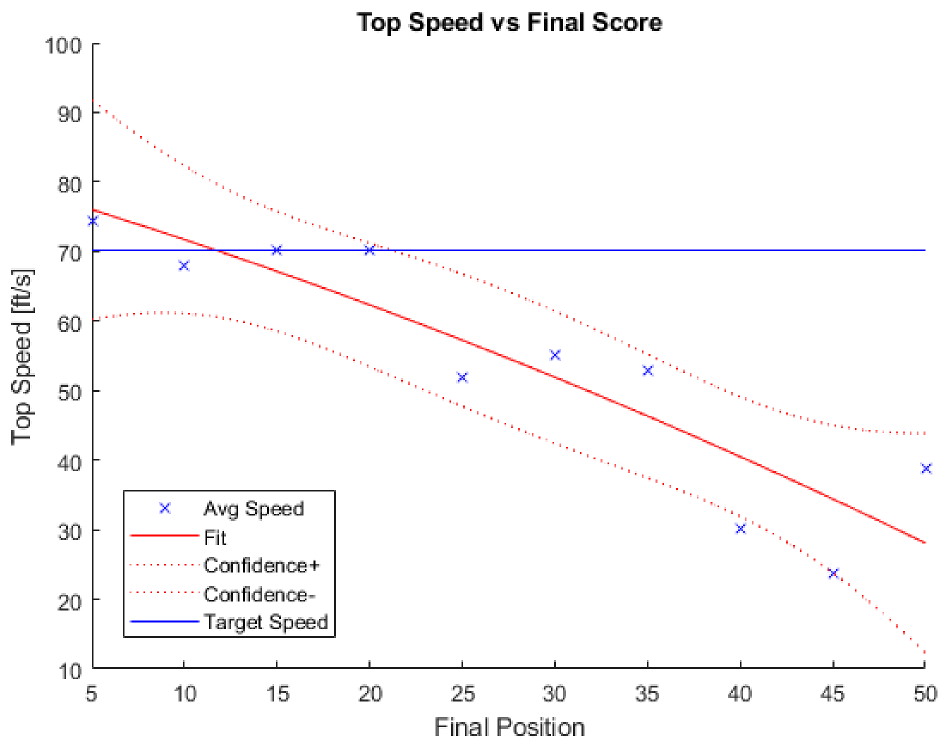


Figure 3.3

Weight Targeting:

Based on historic propulsions and weight data, the team determined that to achieve the desired targeted top speed, the plane would need to weigh less than 7lbs. This corresponds with the weight of carrying 6 attack stores and the necessary mounting hardware.

Analysis Conclusion:

From the preliminary analysis performed, the team determined that the design of the aircraft would have a goal of achieving a top speed of 70ft/sec, and carrying 6 attack stores while keeping the total weight under 7lbs.

3.3: Configuration Selection:

Design Process

After deciding a target speed, weight, and attack store capacity, the team decided which features would be optimum for achieving these goals. Major design elements included the shape of the fuselage and wings, the landing gear, tail, control surfaces, and motor configurations. The team considered several configurations and used Figures of Merit (FoM) to help determine the optimal solution for this year's design.

Figures of Merit

The team employed a selection process that has been used for many years. The procedure can best be described by the following:

"Each FoM was weighted based upon a 100 point scale dependent on a trait's importance to the success and ultimate score of the design with more significant aspects possessing greater weights. The weight of these traits vary between FoM as each component of the aircraft possesses different needs and considerations." [4]

Selection Weighting System

To determine the weighting of each factor, the team referred to *Fundamentals of Aerodynamics* by John Anderson to determine the relevant theory for each component considered [1]. Next, an assortment of design concepts were explored, and based off the theory assigned a score from one to five. This score was based on the appropriateness of a design concept to meeting the design requirements compared to the other possibilities considered. Each score's qualitative meaning is shown in ***Figure 3.3*** [4].

1	Poor
2	Below Average
3	Average
4	Above Average
5	Excellent

Figure 3.3: Selection Scoring

Aircraft Configuration

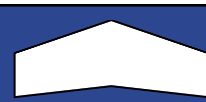
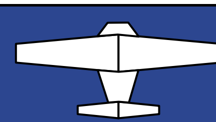
FOM	Weight	 Flying Wing	 Conventional
Weight	40	4	5
Structural Capability	20	4	4
Manufacturability	10	3	5
Stability	30	3	4
Total	100	360	450

Figure 3.4: Aircraft Configuration Table Figure of Merit

For aircraft configuration, shown in ***Figure 3.4***, the main factors considered were weight and stability. Weight was a highly ranked factor as it impacts the final speed of the plane, as explored in section 3.2. Stability was also determined to be a crucial factor because of the additional loads of the attack stores and radome, as well as the extra drag associated with them. Structural capability was the next greatest factor, and ease of manufacturability was weighted as a low priority. From this process, the team selected a conventional aircraft layout for the 2019 competition.

Fuselages

FOM	Weight	Round	Horizontal Rectangle	Vertical Rectangle
Weight	30	3	3	2
Drag	40	3	2	2
Structural Capability	20	4	2	2
Manufacturability	10	1	3	3
Total	100	300	240	210

Figure 3.5: Fuselage Configuration Figure of Merit

Figure 3.5 shows the FoM for fuselage cross section selection. Weight and drag were the main factors considered when selecting the general shape of a fuselage. This is because a lower weight and drag will increase the potential speed of the final plane. The team selected circular cross sections because of their reduced surface area (leading to less weight), structural capabilities, and the ability to streamline the fuselage. While it is the most difficult to manufacture, the team decided that the benefits to aerodynamic performance would be worth the additional challenge of constructing the fuselage.

Propulsion Systems

The motor selection process involved considering the following configurations used in previous years [4][5]:

- Single Tractor: A single motor mounted at the nose of the aircraft
- Dual Tractor: Two nacelle-housed motors
- Single Pusher: A single motor mounted behind the wing of the aircraft.

Figure 3.6 shows the FoM used in selecting the propulsion system configuration for the 2019 competition. The main factors considered were weight, aerodynamic efficiency, stability, and ease of assembly. Weight and ease of assembly were the most important considerations as the team wanted to ensure the target weight could be met, and that the motor could be easily accessed for maintenance when necessary. The single tractor was selected for its weight and ease of assembly.

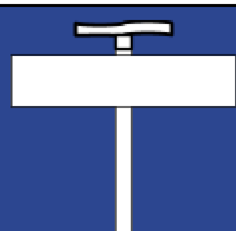
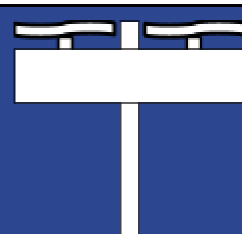
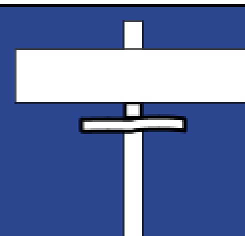
FOM	**Weight**	 **Single Tractor**	 **Dual Tractor**	 **Single Pusher**
Weight	35	5	4	5
Aerodynamic Efficiency	20	3	5	3
Stability (CG balancing)	20	5	4	3
Ease of Assembly	25	5	3	3
Total	100	**460**	395	370

Figure 3.6: Propulsion Configuration Figure of Merit

Wings

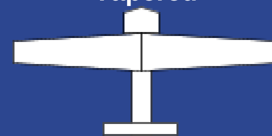
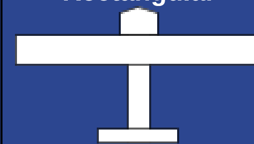
FOM	Weight	Elliptical 	Tapered 	Rectangular 
Ease of Fabrication	20	1	4	5
Aerodynamic Efficiency	30	5	3	2
Weight	20	4	4	3
Strength	30	3	3	5
Total	100	340	340	370

Figure 3.7: Wing Shape Figure of Merit

Figure 3.7 shows the FoM used to determine the wing shape. The wing shape was selected by considering ease of fabrication, aerodynamic efficiency, weight, and strength. The team considered elliptical, tapered, and rectangular wing shapes. Rectangular wings were chosen because of the ease of manufacturing and their strength. Because the attack stores need to be mounted beneath the wing, the wing's resistance to bending moment was considered a high priority for this year's competition.

FOM	Weight	Rounded 	Angular 	Hoerner 	None 	Winglet 
Weight	25	4	4	3	5	2
Aerodynamic Efficiency	30	3	2	4	0	4
Ease of Fabrication	45	3	3	3	5	2
Total	100	325	295	330	350	260

Figure 3.8: Wingtip Configuration Figure of Merit

Figure 3.8 shows the FoM used to determine whether to use winglets or not. The team selected no wingtips due primarily to the ease of manufacturing a wing without wingtips. Because the minimum wingspan for the 2019 competition is 4 feet, the induced drag will be reduced primarily by the increased aspect ratio relative to previous years. Therefore, the team decided to prioritize weight and ease of fabrication.

Landing Gears

For the landing gear, the main factors considered were maneuverability and stability on takeoff. In previous years, the team has had problems with the landing gear causing the aircraft to not take off straight, which has impacted the mission scores. For this year's competition, the team also needed to consider the design requirement that the landing gear be within 2 feet of the nose of the plane. With these considerations, the team decided to use a 3-wheel landing gear, with the wheels spaced so that the center of mass would be centered as much as possible.

Tails

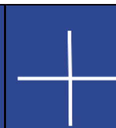
FOM	Weight	 Ring	 Conventional	 Box	 Double Fin	 High T	 Plus
Stability	20	5	2	5	2	4	1
Ease of Fabrication	15	4	5	4	4	4	4
Drag	25	1	5	1	4	5	4
Surface Area	30	3	3	4	4	4	3
Weight	10	2	5	2	4	4	4
Total	100	295	380	325	360	425	310

Figure 3.10: Tail Configuration

Figure 3.10 shows the tail configurations considered. The governing factors for selecting the tail include stability, ease of fabrication, drag, surface area, and weight. Because of the additional weight of the attack stores causing a downward pitching moment during Mission 3 and the downwash due to the wings and radome, it was determined that a High T tail would provide the best combination of the configuration factors and provide a means of controlling the stability of the aircraft.

Control Surfaces

FOM	Weight	Full Control	No Rudder	With Flaps
Mass	20	2	3	1
Complexity	30	2	3	1
Stability	40	4	2	5
Manufacturability	10	2	3	2
Total	100	280	260	270

Figure 3.11: Control Scheme Configuration Figure of Merit

Figure 3.11 shows the FoM used to select the control surfaces needed for the aircraft. Three control schemes were selected based on previous year's considerations: full control (aileron, elevator, rudder), no rudder, and full control with flaps [4][5]. Full control was decided to be important for this year's competition to account for yaw control during takeoff and landing, as well as to stabilize the loads from the extra weight of the radome and attack stores.

3.4 Final Conceptual Design

Through analyzing the FoMs and the sensitivity studies for each crucial factor, the team chose a configuration with the following elements:

- Conventional aircraft configuration with rudder control
- High T tail
- 6 attack stores
- Cylindrical fuselage with landing gear
- Single motors/propellers mounted at the nose of the aircraft
- Rectangular wings without wingtips

These conceptual design choices were selected in hopes that they would provide the most solid basis for developing our prototypes and final plane design.

Section 4: Preliminary Design

4.1 Design Methodology:

Structure Design Methodology

The team designed the structural elements of the aircraft to meet the load factor safety requirements while also minimizing the weight of the plane. Material choices were made to select mostly lightweight composite materials which would provide enough strength to resist the maximum loads encountered by the aircraft. Safety requirements specify that the wing would need to withstand load factors between -1 and 2.5 $(-1 \leq n \leq 2.5)$. Assuming a maximum weight of 6 pounds, the team determined that the wings should be designed to resist a maximum of 17.5 pounds of force upward, and -7 pounds of force downward. The structural components were then designed based off these requirements. The significant loads to be considered are summarized below:

- Take Off – 17.5 pounds lift
- Dive – 7 pounds downward force
- Thrust – 5 pounds horizontal to aircraft
- Drag – 5 pounds at max speed

Aerodynamics Design Methodology

The aerodynamics subteam focused on aerodynamic coefficient selection (C_L, C_D, C_m), and sizing of airfoils for manufacturability and strength. The team used XFLR5, a Computational Fluid Dynamics program, to analyze these characteristics for the wing and tail of the aircraft. This was then used to approximate the overall lift and drag of the aircraft. A rectangular wing design was chosen to maximize wing area and be easier to mount attack stores, as well as for ease of manufacturing. The vertical stabilizer uses a symmetric airfoil while the horizontal stabilizer has the same airfoil as the main wing. These configurations were determined from the analysis done using XFLR5.

Propulsions Design Methodology

The main design concerns for the propulsion system for this competition is to provide enough thrust to overcome drag at cruise speed, to accelerate the plane quickly enough for a short take off, and to supply enough power throughout the entire mission. This involves matching a battery, motor, and propeller to gain optimal results. The parameters considered for the battery is maximum allowable current, voltage, and capacity. Motor selection was based on KV, power rating, and efficiency. Finally, the propeller's pitch, diameter, and efficiency were taken into consideration.

The basis of the propulsion design starts with the power required for flight. The power required for steady level flight and takeoff are the main limiting factors for the propulsion system. Power required for flight can be calculated using the following equation:

$P_{Required} = T*V$

T: Thrust required to overcome Drag

V: cruise speed velocity

$P_{Required}$: power required

The aerodynamics team estimates total drag to be 5 lbs and an average flight speed of 50ft/sec will be required to complete 6 laps. Using the drag force to estimate thrust and a maximum velocity of 70ft/sec, the power required for cruise flight is 547 watts. The power needed for takeoff is also required and can be found using the same equation again. This year's mission requires a 10 foot take off distance which is a formidable challenge to the propulsion system. By using the basic kinematic equation:

$a = V_f^2/2*x$

a: acceleration

V_f: Final Speed

x: Distance

By using aerodynamics subteam's estimate of 36.6 ft/sec for takeoff, the acceleration comes to around 67.57 ft/s^2 (2.1g). Taking this speed into account, it was found that the plane would require 831 watts of power to take off from the ramp. Cruise speed may only require 547 watts for power, but the takeoff requirement is certainly the limiting factor for the propulsion system. This is the largest expected power required.

4.2 Mission Modeling and Optimization Analysis

In previous years, the team has developed a mission model using MATLAB. This mission model takes into account the relevant vehicle information, as well as environmental conditions to predict flight performance. The team this year has opted to use this model adjusted to our parameters this year to determine the predicted outcome in competition flight. Thrust, weight, lift, drag, top speed, air density, airspeed, and wind gusts are all included in this mission model. ***Figure 4.1*** shows the flight path model that is used to determine these characteristics. This flight path model has been used for the past several years[4][5]:

- Launch (red): The aircraft starts with a 50mph velocity
- Liftoff (blue): The aircraft achieves minimum flight speed of 30mph and begins climb to 100ft.
- Straightaway 1 (gold): after achieving altitude the aircraft flies level until flag 1 (500ft from launch)
- 180 degree turn 1 (green): after passing flag 1 the aircraft initiates a 180 degree right turn
- Straightaway 2 (purple): After completing the 180 degree turn, the aircraft flies level for 500 feet
- 360 degree turn (black): The aircraft completes a 360 degree left turn.

- Straightaway 3 (Grey): After completing the 360 degree turn the aircraft flies level to flag 2 (500 ft)
- 180 degree turn 2 (Brown): After passing Flag 2 the aircraft initiates a 180 degree turn.
- Straightaway 4 (Pink): after completing the 180 degree turn the aircraft flies level for 500 feet returning to its starting point and completing a lap.

All subsequent laps start from Straightaway 1 Section of flight, typically only the first lap is modeled.

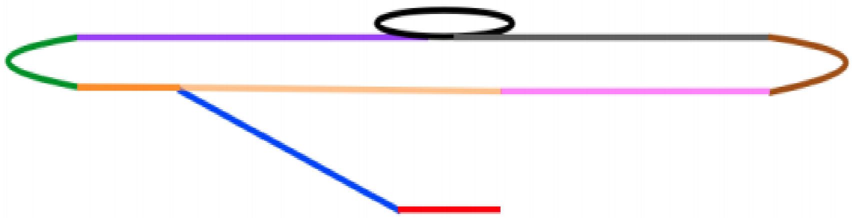


Figure 4.1 Model Flight Path [4]

Mission Model Uncertainties

Previous testing has shown that the mission model carries some tangible uncertainties, but provides a strong basis for predicting the outcome of the team's performance. The greatest uncertainties in the flight model relate to drag and motor efficiency. Drag is difficult to model because subtle deviations in the shape of an object and the environmental conditions drastically change this parameter. Additionally, manufacturing tolerances can have significant impact on motor efficiency. Less drastic, but still a component, subtle changes in weight and lift can also cause deviation from the model. These factors and other contribute to uncertainties in the mission model, and therefore it is expected that the actual flight capacity will vary from the model. To account for this, the team implemented the use of safety factors where necessary to ensure the success of the design[4].

4.3 Design Trade Studies:

Propulsions

The propulsions system design for the plane involves the consideration of battery cell capacity, battery size, and the motor characteristics. One of the design requirements is that only Nickel Metal hydride (NiMH) or Nickel Cadmium (NiCd) cells can be used for the power supply. In comparing the two, the team chose NiMH cells because of their higher energy density. From historic data, the team noted that NiMH cells provide between 77.3 and 78.3 W-hr/kg while NiCd cells provide only 48.5 W-hr/kg [4]. With a top speed of 70ft/sec and an assumed thrust of 5lbs, the power required during steady-level flight as determined to be 547 Watts. This figure increases to 831 during takeoff (see section 4.2). Therefore, the team wanted to use the most energy dense battery cell to limit the weight of the battery. Having selected the desired cell material, the team decided between three types of market available cells for the final battery selection. ***Figure 4.2*** shows these three options.

Battery Description	Capacity (mAh)	Weight (ounces)	Size (inches)
Elite 1500 2/3A	1500	0.81	1.1x0.7x0.7
Elite 2100 4/5A	2100	1.15	1.7x0.7x0.7
Elite 5000 Sub-C	5000	2.37	0.88x1.68x4.50

Figure 4.2: Battery Cells Considered

For each battery cell type, there were also battery configurations considered in ***Figure 4.3.***

Capacity (mAh)	Cell Count	Weight (g)	Voltage (V)	Max Continuous Draw (amps)	Max Power (Watts)	Capacity/weight (mAh/g)
1500	10	229.7	12	30	360	6.53
2100	10	326	12	30	360	6.44
5000	10	796.8	12	50	480	7.35

Figure 4.3: Battery Packs Considered

Due to the power requirements during takeoff, the Elite 5000 Sub-C battery cells were selected, configured in a 12-cell battery which would provide 5000 mAh of use during flight.

After selecting the battery, motor and propeller configurations were considered that would enable the team to reach its speed and time goals/requirements. ***Figure 4.4*** outlines the motors considered for selection. ***Figure 4.5*** shows the propeller configurations considered.

Motor	kV	Max watts (W)	Weight (oz)
Scorpion 3026 V2	890	960	7.23
Scorpion SII-3020	1110	840	5.86
Turnigy L3010C	1300	420	3.06
Turnigy LD2840A	1800	400	3.28

Figure 4.4: Motor Selection

Propeller	Thrust(oz)	Voltage(V)	Current(A)	Pitch speed(mph)
8”x8”	49.82	12	40.26	82.9
9”x9”	67.68	12	45.64	63.9
10”x10”	88.43	12	52.36	74.6

Figure 4.5: Propellers for Scorpion SII-3020 Considered

After analyzing various combinations of motors and propellers, the team determined that the Scorpion 3026 V2 paired with a 10in by 10in propeller would offer the best results for meeting our design parameters.

4.4 Aerodynamics

In selecting airfoils for the main wing and tail, the team focused on highly cambered airfoils that performed well at low Reynolds numbers. Proper airfoil selection is key to achieving desired aircraft performance. The thousands of airfoil choices were narrowed down to a hundred airfoils that provide high lift at low Reynolds Numbers (Re). From there the selection was further reduced to 32 choices before the final airfoil of E216 was selected. The E216 Airfoil is shown in ***Figure 4.7***. Factors included in narrowing down and selecting airfoils were performance characteristics at three Re values, calculated using chord length, dynamic viscosity of air, and airspeed. Reynolds number at maximum airspeed of 70ft/s (~290 000), Reynolds number at takeoff (~105 000), and Reynolds number during climb (~250 000) were all used to determine the best airfoil to select. Performance characteristics included stall angle, coefficient of drag, ease of fabrication and structural integrity of the wing. Several high-performance choices with high camber or very thin designs were rejected due to difficulty of fabrication and structural weakness. Previous years of structural testing have demonstrated that a thickness of at least 10% is needed to provide structural rigidity with light composite and foam construction [4][5]. Low thickness airfoils do not have high enough inertia or allow enough room for the structural members needed to provide adequate stiffness. Additionally, complex airfoil shapes with sharp leading edges and high camber can be difficult to manufacture to design specifications. These airfoils were rejected because imperfections in manufacturing will cause performance characteristics different than those designed. The team used XLFR5 to examine the lift, glide ratio, and drag polar to determine optimal airfoils. These analyses for 6 airfoils (E216, AH 79-100, DAE31, FX 76-MP-120, S4022, SG6043) at Reynolds number of 250,000 and 88 ft/s are included in ***Figure 4.6***.

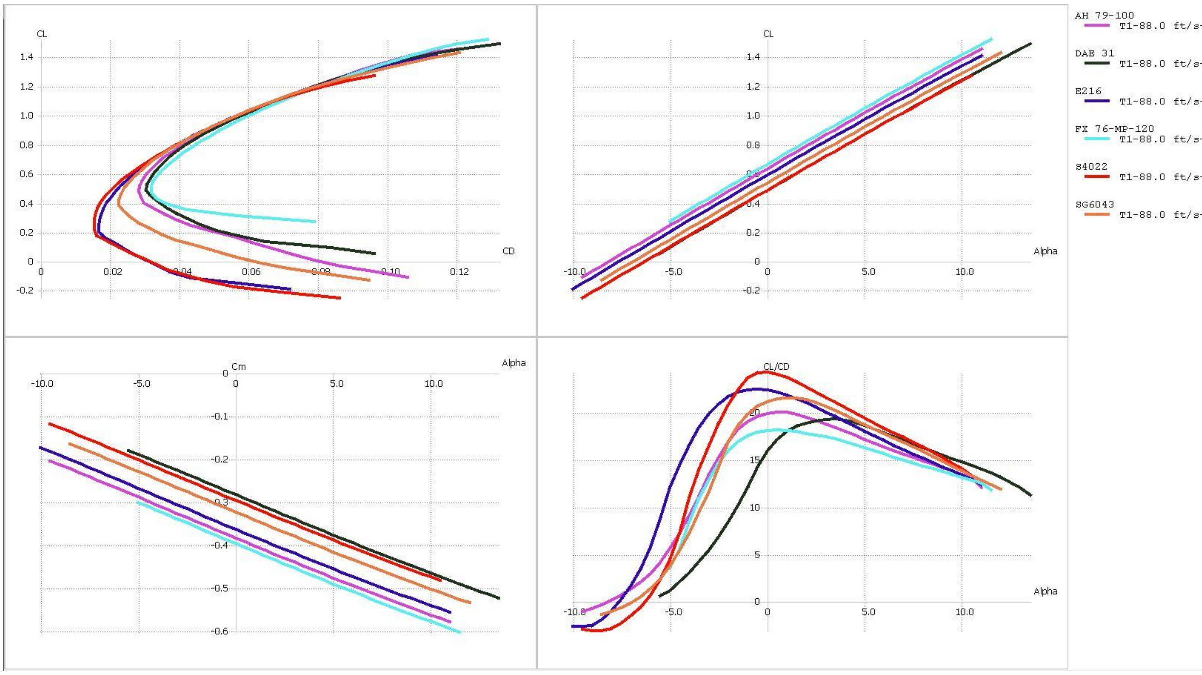


Figure 4.6: Comparison of Aerodynamic Coefficients Between Various Airfoils

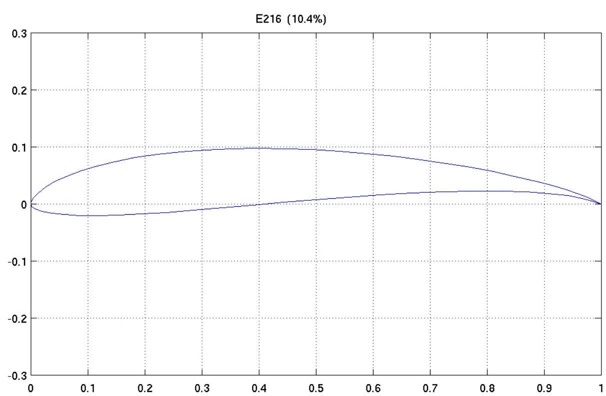


Figure 4.7: Airfoil E216

Wing Sizing

In sizing the wing, the necessary area, wingspan and airfoil shape needed to be considered to select a final chord and span length. A safety factor of 1.1 was used to determine the wing sizing based on the theoretical results determined through the analyses of various airfoils. For determining the size, the team used a theoretical takeoff velocity of 36.6 ft/sec and an amplified weight of 7.7lbs to account for the safety factor necessary. The team then used the equation $S = \frac{2.5*W_{SF}}{\rho*V_{Takeoff}^2*C_L}$, where S is planform area, p is air density, $V_{takeoff}$ is the velocity at takeoff, W_{SF} is the safety factor weight, and C_L is the maximum lift coefficient [1]. From this calculation it was determined that a wing area of 784.5in^2 would be required for the main wing. In keeping with the required folding dimensions, the team selected a 12in chord for the main wing with a span of 65.375in. This enables the plane to be folded into storage position to roll through the required 3ft x 2ft x 2ft box. The horizontal stabilizer and vertical stabilizer size were determined by considering the required tail lift for stability at the greatest expected load factor of 2.5. From this analysis, it was determined that the horizontal would be 108 in^2 with a 6in chord and an 18in span. The horizontal stabilizer uses the same airfoil as the main wing. The vertical stabilizer was sized to be half the area of the horizontal stabilizer with an area of 54 in^2, a chord length of 6in, and a height of 9 inches. The vertical stabilizer uses a symmetric airfoil so as to not generate any horizontal forces which would cause roll instability. ***Figure 4.8*** Shows a table with each aerodynamic parameter for the design. ***Figure 4.9*** Shows the drawings for the final wing and tail designs.

	Main wing	Horizontal stabilizer	Vertical Stabilizer
Tip Chord (in)	12 (E216)	6 (E216)	6 (NACA 0010)
Root Chord (in)	12 (E216)	6 (E216)	6 (NACA 0010)
Span (in)	65.375	18	9
Area (in^2)	784.5	108	54

Figure 4.8: Table of Aerodynamic Design Parameters

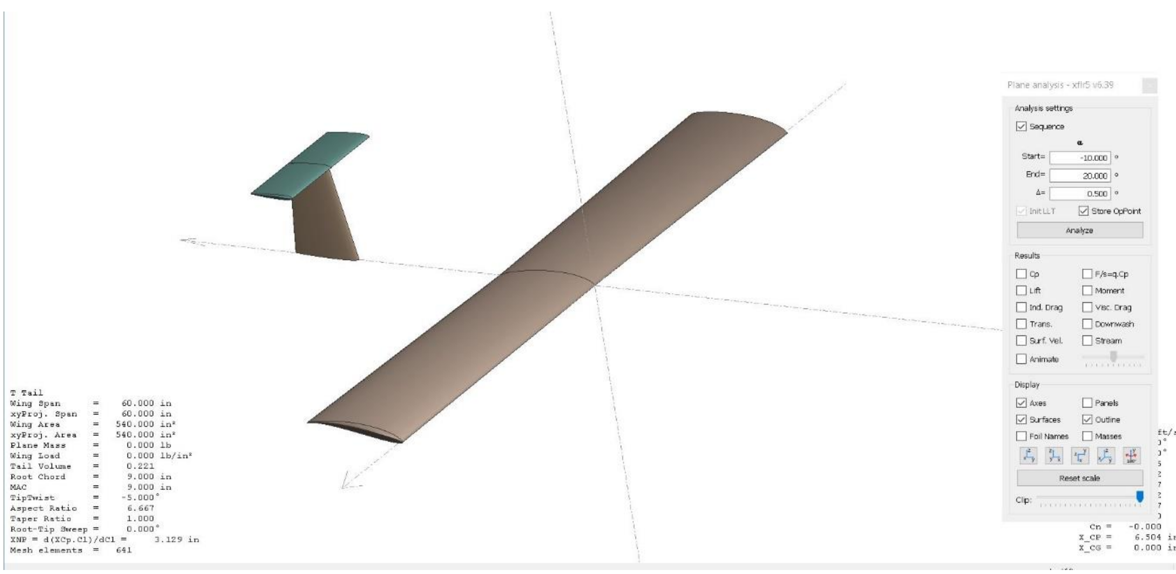


Figure 4.9: Final Wing and Tail Designs

Wing Characteristics

The final wing characteristics are shown in ***Figure 4.10***, ***Figure 4.11***, and ***Figure 4.12***

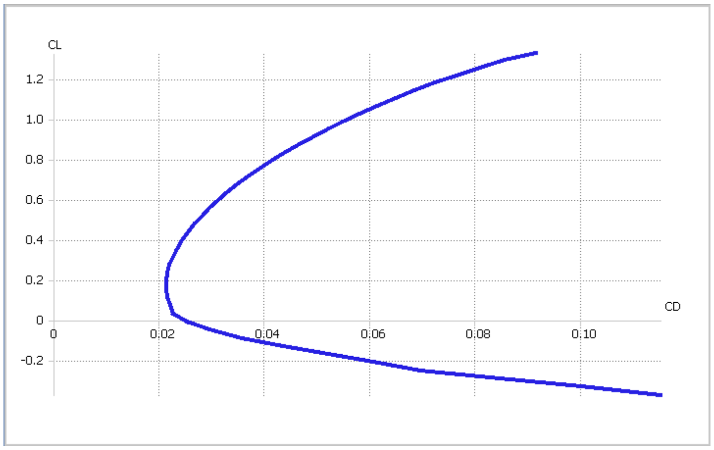


Figure 4.10: Coefficient of Drag plotted versus Coefficient of Lift

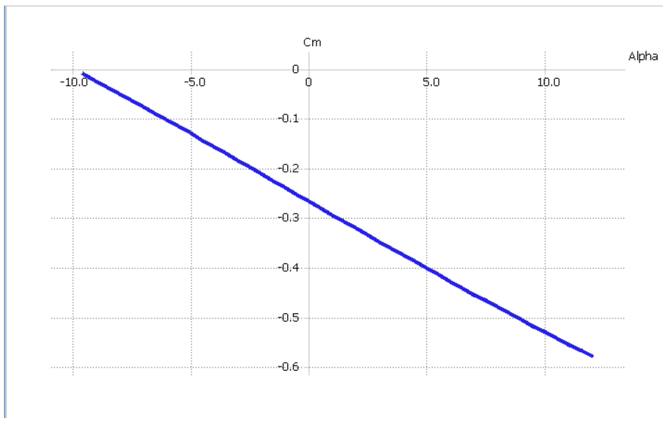


Figure 4.11: Coefficient of Moment plotted versus Angle of Attack

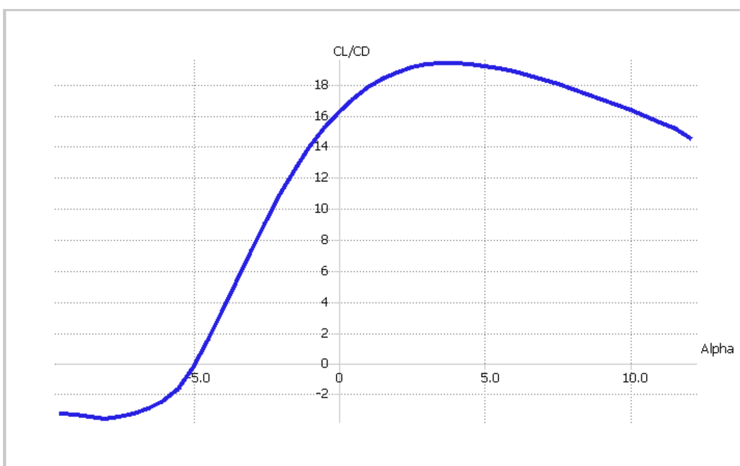


Figure 4.12: Glide Ratio plotted versus Angle of Attack

4.5 Stability and Control:

Static Margin

The static margin determines the longitudinal stability of the plane. If the static margin is positive, it can be said that the plane is stable. For this to occur, the Center of Gravity (CG) must be forward the neutral point [4]. The team calculated the static margin using the equation $S.M. = \frac{N.P. - X_{CG}}{MAC}$, where:

$$MAC = c * \frac{2}{3}$$

SM is static margin, NP is the displacement of the neutral point from the nose of the plane, X_{CG} is the displacement of the CG from the nose of the plane, and c is the wing chord [4][5]. XFLR5 was used to calculate a neutral point of 15in, and with the center of gravity determined to be at 11.98in (worst case), the MAC was found to be 8.0. Using these values, the S.M. was calculated to be 0.378. Therefore, the aircraft will be stabile because the static margin is positive.

4.6 Expected Performance:

Using the preliminary design, the team was able to use our mission model to estimate the aircraft's performance in the three missions. ***Figure 4.13*** shows the expected mission performance, assuming the team scores moderately in Mission 2 (speed factor of 0.5). Based on the mission model times, the team decided that the obtained lap times were adequate for pursuing the selected design.

Mission 1		Mission 2		Mission 3	
Lap Time (s)	85	Lap Time (s)	98	Lap Time (s)	95
Time Required (s)	100	Time Required (s)	100	Time Required (s)	100
Mission 1 Score	1	Mission 2 Score	1.5	Mission 3 Score	8

Figure 4.13: Expected Mission Performance

Section 5: Detailed Design

During the final design stage, the component decisions were finalized and optimized for each mission. This analysis included flight performance predictions for each mission.

5.1 Final Design Parameters

The finalized design parameters, including electrical, structural and mechanical components are outlined in ***Figure 5.1***.

Overall Dimensions		Fuselage	
Length	37.25 in	Length	36 in
Stored Width	34 in	Largest Diameter	5.5 in
Height	5 in	Minimum Diameter	1 in
Wing		**Vertical Stabilizer**	
Span	65.375 in	Root Chord	6 in
Chord	12 in	Tip Chord	6 in
Area	784.5 in^2	Height	9 in
Aspect Ratio	5.447	Area	54 in^2
Horizontal Stabilizer		**Motor/Battery**	
Chord Length	6 in	Motor	Scorpion 3026 V2 890 kV
Span	18 in	ESC	ICE2 HV60
Area	108 in^2	Battery Model	Elite 5000 Sub-C
Controls		Number of Cells	10
Servos	hs-5152mg	Pack Voltage	12 V
Stall Torque (oz.in)	42	Pack Weight	28.44 oz
Speed (sec/60deg)	.17		

Figure 5.1: Finalized Design Parameters

5.2 Structural Characteristics and Capabilities

The team used sketches detailing the places where external loads would be applied to determine the requirements for the aircraft's structural components. ***Figure 5.2*** shows the free body diagram that was used for determining the structural needs for resisting external loads.

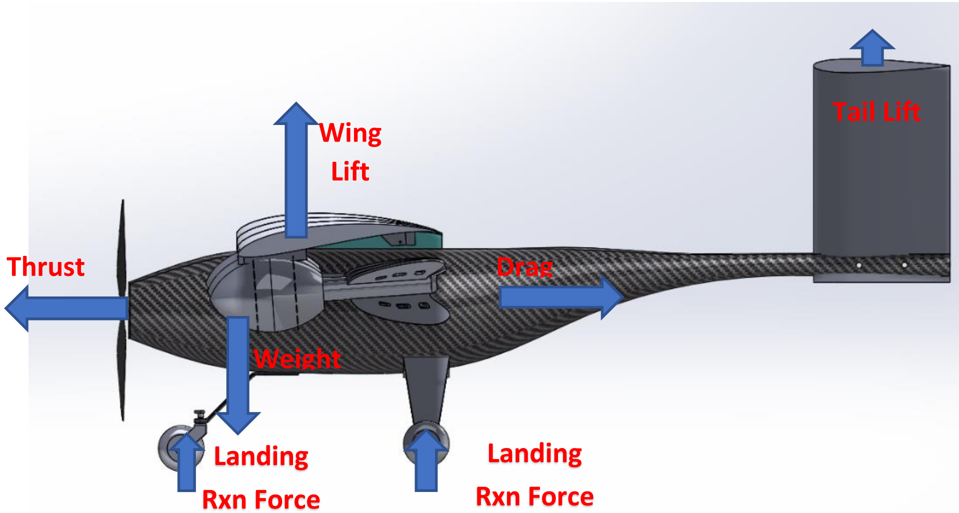


Figure 5.2: Load Diagram

The team identified critical structural locations on the aircraft through the free body diagram analysis. These loads were then factored into the materials and structures used to avoid structural failure at an expected load location. ***Figure 5.3*** shows the structural elements, associated loads, and design solutions used to account for them.

Structural Element	Applied Load	Description of Design
Landing Gear	Impact upon landing	Lightweight and stiff. Able to flex but not buckle during landing.
Fuselage	Point loads at each element connection	Carbon fiber composite with hollow cross-sectional area to diminish bending.
Wing and Tail Connections	Aerodynamic loads	Wing and tail connect to the fuselage via epoxy and nylon bolts to transfer forces.
Wing Structural Spars	Compression and tension due to aerodynamic loading	Unidirectional carbon fiber spar embedded along the quarter-chord to counter bending moment and shear.
Motor Mounts	Tension and torque due to thrust and rotation	Motor mount surface embedded in carbon fiber composite fuselage

Figure 5.3: Table of Critical Structural Elements

5.3 System Designs, Component Selection and Integration

Fuselage Structural Design

The fuselage structure houses the controls electronics, batteries, and motor. The team designed the fuselage to be the main structural element of the plane, with the carbon fiber composite base providing the foundation for mounting the wings, radome, and attack store release mechanisms. The fuselage is built with circular cross sections, with a maximum diameter of 5.5 inches and a minimum of 1 inch.

Attack Store Attachment

The attack stores are mounted in 3D printed holders and mounted under the wing as shown in. The attack stores are released by a servo mounted in the fuselage that will unspool strings holding them in. The release of tension will allow the attack stores to fall. Each attack store will be spooled around the main spool a different number of times, providing the necessary mechanism for varying deployment during each load.

Radome:

The radome is mounted on a vertical standoff that will be formed using the NACA 0010 symmetric airfoil used on the vertical stabilizer. This standoff is connected to the main fuselage using 2 nylon bolts. A 360-degree continuous rotation servo is embedded into the airfoil that will enable the radome rotation necessary for this year's competition.

Wing Structure

The wing is constructed out of foam with a carbon fiber composite spar along the quarter-chord. The wing shape is cut out of foam using a hot wire foam cutter. The spar is then wrapped around the wing and left to cure in a vacuum bag. The wing is secured to the fuselage by two ¼ inch bolts.

Wing Folding Mechanism:

The wing folding mechanism consists of a 2-bar linkage driven by a linear actuator (worm driven lead screw) which pivots the wings about hinges positioned along the wing span such that the plane can fit within the 3ft x 2ft x 2ft storage position required. The locking mechanism is inherent to the worm drive, as it would take more load to back drive the worm gear than is expected to be encountered during flight.

Tail Structure and Attachment

The tail is constructed in the same manner as the wing. The horizontal stabilizer and vertical stabilizers are connected using epoxy to form the tail assembly. The tail assembly is then epoxied onto the fuselage of the aircraft and bolted with 2 nylon bolts to provide further resistance to bending moment.

Propulsion System

The final propulsion configuration is the Scorpion 3026 V2, 890 kV motor, powered by a 10 cell 12v 5000mAh NiMH battery pack. This setup provides 960W peak power and a pitch speed of 72 feet/sec when coupled with an 10in x 10in pitch propeller.

5.4 Weight and Balance

Figure 5.4 shows the weights and balance chart for our plane. Locations in the x direction are measured from the nose towards the tail. Locations in the z direction are measured with reference to the thrust line. Positive z direction indicates the point is above the thrust line. Because of the plane's symmetry, they direction measurements parallel to the wing are not considered as they should have relatively little impact on the overall stability.

Component	Case	Weight (oz)	X distance from nose (in)	Z distance (thrust line is Z=0) (in)
Fuselage	**All**	12	4.7	0.5
Motor	**All**	7.3	0.5	0
Batteries	**All**	28.4	10	0
Receiver	**All**	1.22	15	0
Wing	**All**	16	9.6	2.5
Tail	**All**	10	33	7.5
Landing Gear	**All**	3	4	-5.33
Attack Stores	**M3**	18	6.375	0.675
Radome	**M2**	8	21.5	7.75
M1 Total	**M1**	77.9	11.01	1.35
M2 Total	**M2**	85.9	11.98	1.94
M3 Total	**M3**	103.9	10.14	1.22

Figure 5.4: Weight and Balance Table

5.5 Flight Performance Parameters

The team was able to identify relevant flight performance parameters for various angles of attack through the use of CFD analysis. The test cases analyzed were performed at angles of attack of 0, 4, 8, and 12 degrees. These test cases represented the expected parameters for steady-level flight, takeoff, climb, and landing. These values are listed in ***Figure 5.5*** for Mission 1, ***Figure 5.6*** for Mission 2, and ***Figure 5.7*** for Mission 3.

Angle of Attack	C_L	C_D	Turn Rate (deg/s)	Takeoff Weight (lbs)
0	0.40	0.025	12.545	4.87
4	0.73	0.038	17.402	4.87
8	1.06	0.062	20.324	4.87
12	1.25	0.084	23.453	4.87

Figure 5.5: Mission 1 Flight Performance

Angle of Attack	C_L	C_D	Turn Rate (deg/s)	Takeoff Weight (lbs)
0	0.40	0.025	11.485	5.37
4	0.73	0.038	14.385	5.37
8	1.06	0.062	18.233	5.37
12	1.25	0.084	21.487	5.37

Figure 5.6: Mission 2 Flight parameters

Angle of Attack	C_L	C_D	Turn Rate (deg/s)	Takeoff Weight
0	0.40	0.025	10.450	6.49
4	0.73	0.038	15.203	6.49
8	1.06	0.062	17.866	6.49
12	1.25	0.084	20.385	6.49

Figure 5.7: Mission3 Flight Parameters

5.6 Mission Performance Documentation of Final Design

Using the flight parameters explored in previous sections, the team simulated our performance in each mission using a MATLAB developed in previous years [4]. Through this analysis, the team was able to evaluate the strength of the aircraft and use iterative design to improve performance. The simulation implemented uses the following flight parameters to determine potential performance: aircraft loading, airspeed, turn rate, bank angle, climb angle, and altitude [4]. The load factor was also a consideration needed, and was required to be within the range of $-1 < n < 2.5$ with the maximum weight taken into account for loading. Figure 5.8 and Figure 5.9 show the simulated performance of the aircraft for missions 2 and 3. As shown. The aircraft stays within the required load envelope.

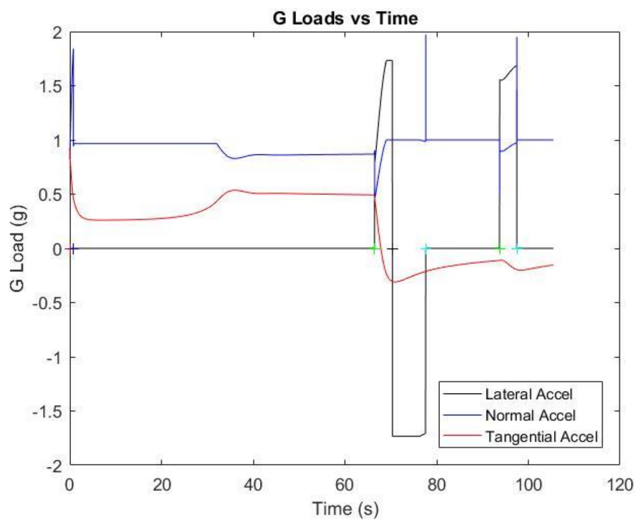


Figure 5.8: Wing Loading—Mission 2

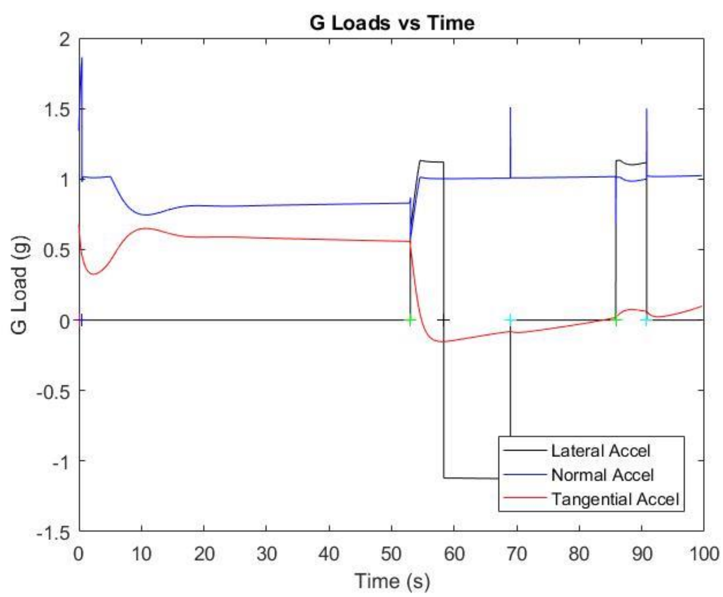
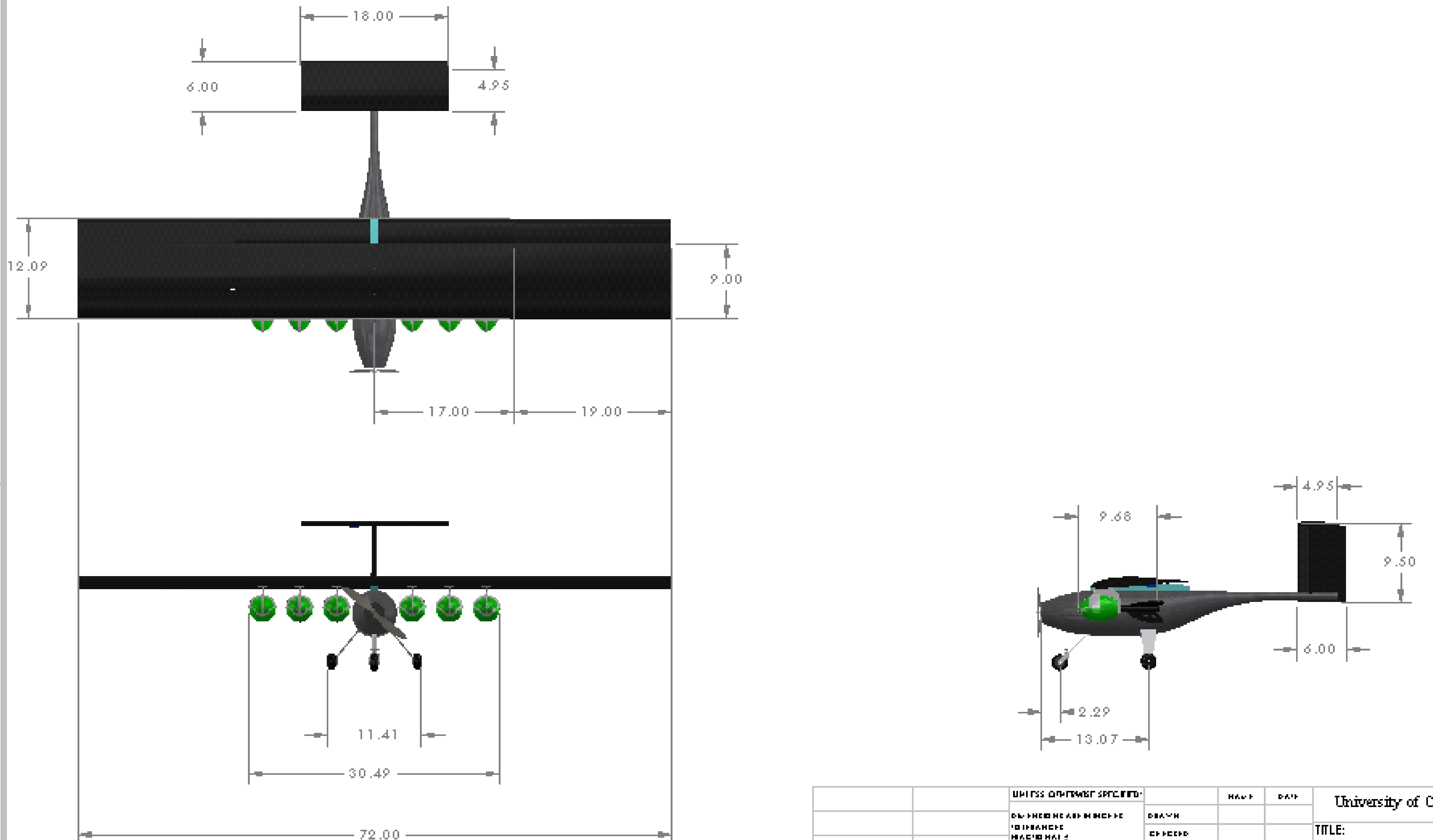


Figure 5.9: Wing Loading—Mission 3

5.7: Drawing Package:

The following 4 pages are the drawing package for the UCSD 2019 DBF competition aircraft. In order as presented, they include a three-view drawing, the structural layout, the systems layout, and the payload accommodation drawing.



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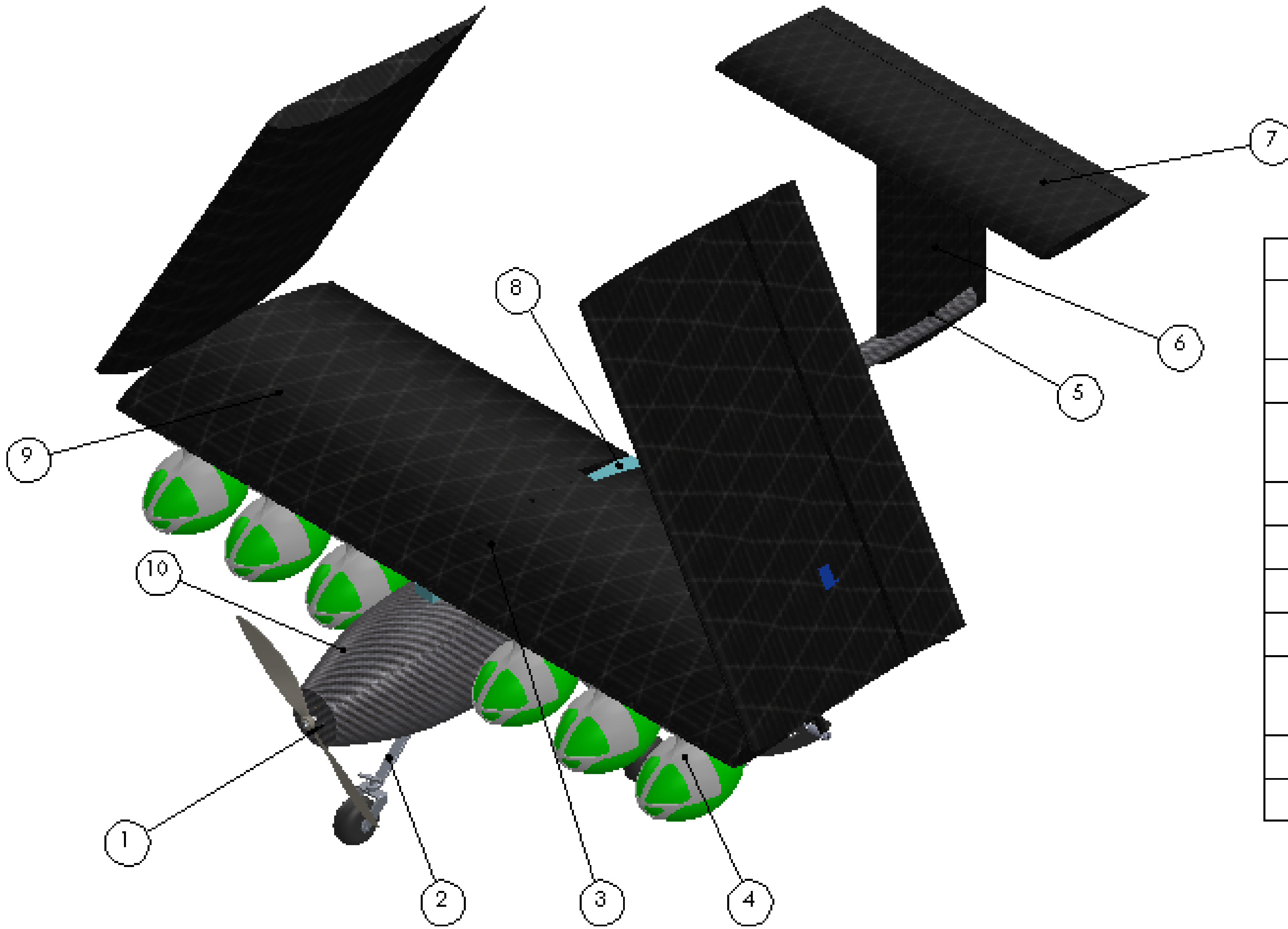

Number	Component
1	Mounting Holes for Motor
2	Front Landing Gear
3	Embedded Spar along Wing
4	Attack Store Rack
5	Slot for Tail
6	Vertical Stabilizer
7	Horizontal Stabilizer
8	Wing Mount Bracket
9	Main Wing
10	Fuselage

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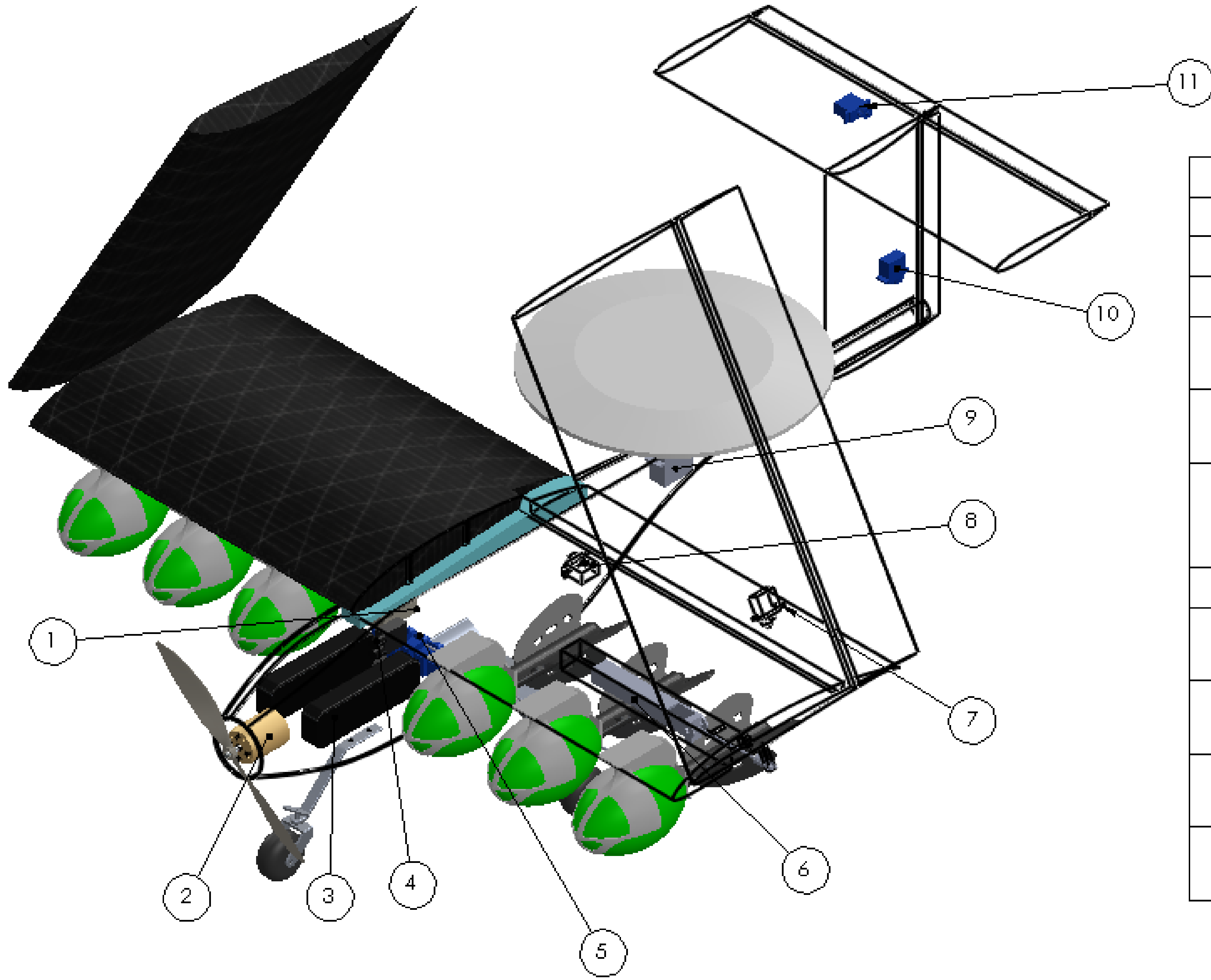

Number	Component
1	Reciever
2	Scorpion 3026 V2 Motor
3	Batteries
4	Electronic Speed Controller
5	Dropping Mechanism Servos
6	Folding Mechanism Linear Actuator
7	Outer Aileron Servo
8	Inner Aileron/Flap Servo
9	Radome Continous Rotation Servo
10	Rudder Control Servo
11	Elevator Control Servo

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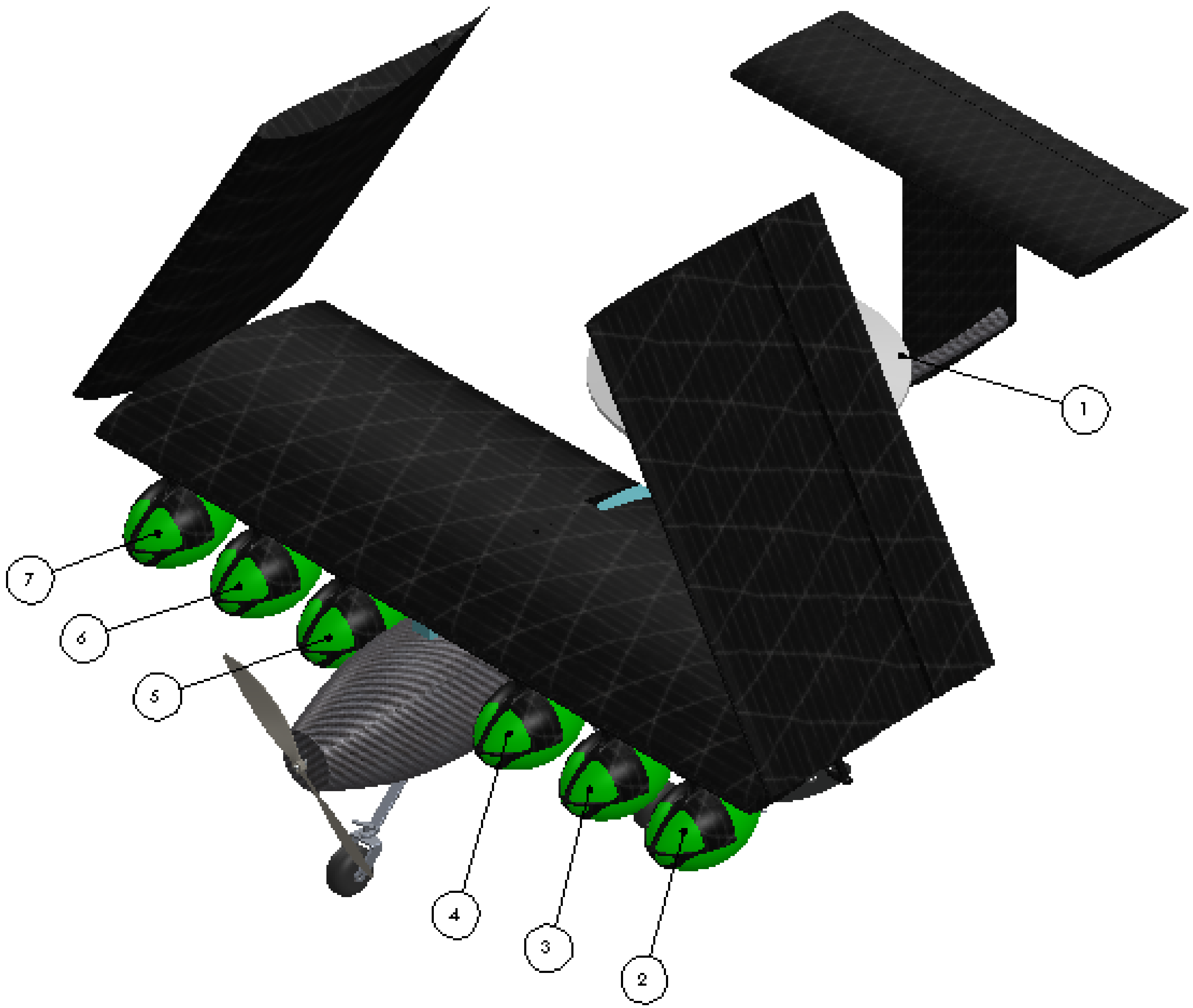

Number	Component
1	Radome
2	Attack Store 1
3	Attack Store 2
4	Attack Store 3
5	Attack Store 4
6	Attack Store 5
7	Attack Store 6

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Section 6: Manufacturing Plan

6.1 Selection Methodology

Different methods for manufacturing components of the aircraft were investigated by the team through the use of Figures of Merit. ***Figure 6.1*** shows the weighting that was used for each FoM in the following section.

Metric	0	5	10	15	20	25	30	35
Weight	35							
Ease of Fabrication	25							
Ease of Repair	5							
Cost	5							
Strength	30							

Figure 6.1: Manufacturing Figure of Merit

Because the one of the primary design objectives is to minimize weight to increase speed, the weight was given the highest weighting in choosing manufacturing methods. Strength is second because of the substantial loads of the payload in the 2019 competition. Ease of fabrication was determined to be the third most important to ensure that prototyping and design iteration could be completed efficiently and effectively. The team gave little weighting to cost or ease of repair since both of these don't impact final performance as greatly as the other factors considered.

6.2: Investigation and Selection of Major Components and Assembly Methods

Fuselage

Based on the team's previous manufacturing knowledge, three methods were analyzed for potential use in the fabrication of the fuselage: balsa truss, foam core/composite shell, and carbon fiber composite shell. ***Figure 6.2*** shows the FoM that was used to select the manufacturing method for the fuselage. The following are descriptions of each manufacturing method [4]:

- Balsa Truss**:** A skin of Mylar covering a frame constructed of balsa wood.
- Lost-Foam Core: Carbon fiber and fiber glass is wrapped around a block of foam cut to the desired fuselage shape with hot wires. After curing of epoxy the foam is then melted out using acetone, leaving the carbon fiber/fiber glass fuselage shell.

- Carbon Fiber Mold: Carbon fiber epoxy composite for a primary load bearing spine.

FOM	Weight	Balsa Truss	Lost-Foam Core	Carbon Fiber
Weight	35	5	4	5
Ease of Fabrication	25	2	4	5
Ease of Repair	5	2	4	3
Cost	5	5	4	3
Strength	30	3	4	5
Total	100	335	400	**480**

Figure 6.2: Fuselage Fabrication Figure of Merit

Carbon fiber composite shell was determined to be the best manufacturing method for building the fuselage thanks to its high strength and its relatively easy molding process. Carbon fiber composite also gave the team an efficient way to reduce weight and streamline the fuselage to diminish the drag experienced as a result.

Wing

Based on the team's previous knowledge, three methods were analyzed for constructing the wing. ***Figure 6.3*** shows the FoM used to consider methods for constructing the main wing. Based on previous manufacturing techniques, the description of each method can be hound below [4]:

- Wood Ribs: Airfoil sections are cut out of balsa using a Laser Cutter, then connected using thin balsa spars and stringers. The wing is then covered in a Mylar skin.
- Foam Core Composite: A foam wing is cut out using a hot wire CNC cutter. A carbon fiber spar is epoxied onto the foam wing, and then covered with fiber glass.
- Hollow Composite with Spar: Similar to the foam core technique, but a fiber spar is included at the quarter chord of the wing to add support, and then the foam core is removed with acetone.

FOM	Weight	Wood Ribs	Hollow Composite	Foam Core Composite
Weight	35	5	4	3
Ease of Fabrication	25	3	4	5
Ease of Repair	5	2	4	4
Cost	5	4	3	3
Strength	30	3	4	5
Total	100	370	395	**415**

Figure 6.3: Wing Fabrication Figure of Merit

The team chose the foam core composite method for manufacturing the wing. This decision was made in large part because of the high strength and ease of fabrication this method allows for. Because the team owns a CNC hot wire foam cutter, this method allows for quick prototyping and design iteration. Furthermore, while this method increases weight it provides a solid mounting surface. This was deemed highly desirable for supporting the linear actuators deploying the wings as well as the attack store holders. This method also allows for drag to be reduced as the wing that results from this method is very close to the airfoil due to the preciseness of the CNC hot wire foam cutter.

Tail

Figure 6.4 shows the FoM that was used to analyze construction methods for the tail. The same methods for construction that were used for analyzing the wing were used for analyzing the tail. Therefore, the same result was yielded.

FOM	Weight	Wood Ribs	Hollow Composite	Foam Core Composite
Weight	35	5	4	3
Ease of Fabrication	25	3	4	5
Ease of Repair	5	2	4	4
Cost	5	4	3	3
Strength	30	3	4	5
Total	100	370	395	**415**

Figure 6.4: Tail Fabrication Figure of Merit

Radome

The same processes were analyzed for constructing the radome and its standoff as the wings and the tail. As a result, the foam core method was selected for its ease of fabrication and strength. ***Figure 6.5*** shows the FoM used to evaluate manufacturing methods for the radome.

FOM	Weight	Wood Ribs	Lost-Foam Core
Weight	35	5	4
Ease of Fabrication	25	3	4
Ease of Repair	5	2	4
Cost	5	4	3
Strength	30	3	4
Total	100	370	**395**

Figure 6.5: Radome Fabrication Figure of Merit

Landing Gear

For constructing the landing gear, the team chose to use aluminum sheet metal because of it ease of use in a sheet metal brake and use with metal sheers. These properties allow the landing gear to be designed and tested in our own workshop as opposed to having to go to another space to construct the landing gear. While aluminum is much denser than carbon fiber composite, an aluminum landing gear will be thinner than a carbon fiber composite to provide the same strength. Therefore, the drag will be reduced by using aluminum to construct our landing gear.

Attack Store, Motor, and Electronics Mounts

For constructing the attack store mounts, the team chose to use 3D printing to manufacture them with PLA plastic. 3D printing allows for fast design iteration as well as the ability to construct a shape that will fit the attack stores perfectly. Likewise, the motor and electronics mounts are 3D printed to take advantage of the same quick prototyping and complex shape capacity.

Key Composite Manufacture Procedure

The primary components of the plane are made with carbon fiber composites, and foam core fiberglass composite. This follows the fabrication procedure that has been used in recent years on our team, and enabled us waste less time having to remake parts that are out of tolerance. The key procedures for this process have been developed over time and are listed below [4]:

1. Design and export the top and side profiles into AutoCAD to generate G-codes for the CNC machine.
2. Use CNC foam cutter to cut foam core into desired shapes.
3. Sand the edges to remove sharp corners created by the foam cutter, especially the leading edge for wing and tail.
4. For payload bay only, cover foam with tape and apply model release
5. Wet lay the unidirectional carbon fiber on cord of wing and tail pieces and center of payload bay for reinforcement.
6. Wet lay with fiber glass.
7. Lay with Mylar with model release applied.
8. Seal and vacuum the bag.
9. For payload bay only, remove the foam core.
10. Sand the edges, and drill holes for mounting.

6.3 Manufacturing Plan:

For the 2019 competition, the team followed the manufacturing plan laid out in ***Figure 6.6***. More time was spent in the beginning of the year going through the design process and after the initial prototype, the fabrication process sped up.

Week of the Quarter	1	2	3	4	5	6	7	8	9		1	2
Payload Bay												
Wing												
Tail												
Landing Gear												
Assemble		`										
Spare Parts												

Figure 6.6: Manufacturing Plan Gantt Chart

Section 7: Testing Plan

7.1 Aircraft and Subsystem Testing Plan

The team has made a testing plan to gather data to be used in optimization of the aircraft design. This test schedule will include tests for all subsystems. ***Figure 7.1*** shows the test schedule that the team has followed during the 2018-2019 competition season.

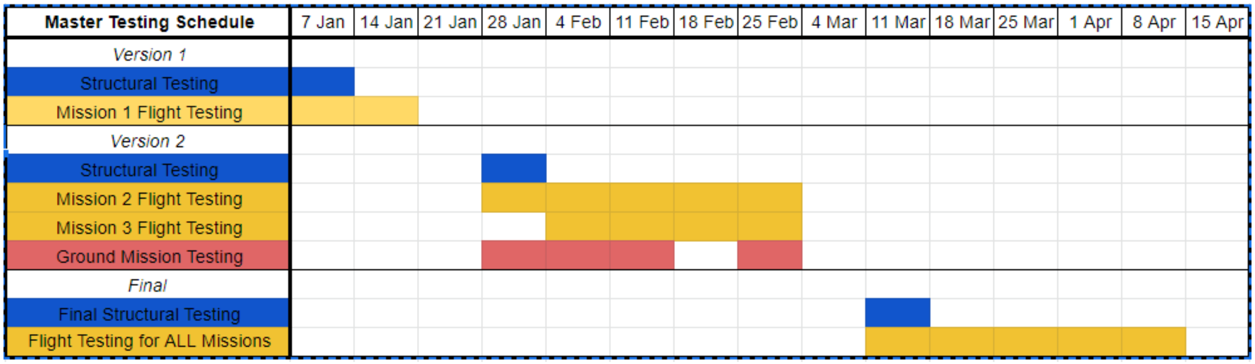

Figure 7.1 Master Test Schedule

Propulsion Testing

Static motor thrust tests were conducted using a motor test stand (RC Benchmark Dynamometer). This system measured thrust, RPM, voltage, and current while ramping up the ESC signal. The test results for the Scorpion 3026 V2 with a 10in x 10in propeller are shown in ***Figure 7.2***.

Motor Tested	Propeller	Thrust (lb)	Pmax (Watts)	Vo (V)	V at Imax (V)	Imax (Amps)
Scorpion 3026 V2	**10" x 10"**	5.6	842	0.5	12.2	54.5

Figure 7.2: Motor Testing Results

Structural Testing

Several tests were performed by the team on structural elements, especially the wings and fuselage. Testing the stresses and structural integrity of the wing was performed by placing weights along the span of the wing and balancing the wing from the wing tips. This wing tip test revealed that the wing can withstand a total force of about 21lbs, which is well in excess of the 16.25lbs expected at the positive high load factor under the maximum weight. This verifies that the plane can withstand the loads expected during flight.

7.2 Flight Testing

Test flights were seen as important to test full mission performance for various parameters. Test flights were to be conducted to correct for inaccuracies in the model, instability, and unforeseen problems by gradually increasing the loading of the aircraft to see how these parameters change. The test plan is detailed below in ***Figure 7.4***. Designations are the same as was used in previous years, and can be defined by: Version-flight (maiden flight MF, Missions M#) [4].

Flight Number	Designation	Payload
1	1-MF	None
2	1-M1	None
3	2-MF	Radome
4	2-M2	2 attack stores
5	2-M3	4 attack stores
6	F-MF	None
7	F-M2	4 attack stores
8	F-M3	6 attack stores

Figure 7.4: Flight Testing Table

7.3 Flight Testing Checklists

Pre-Flight Checklist

The following checks are performed five minutes prior to flight [4].

Pre-Flight Checklist			
Propulsion		**Payload**	
Right Propeller?	☐	Weight Verified?	☐
Propeller Secured?	☐	Payload Secured?	☐
Batteries Charged?	☐	**Aircraft**	
Batteries Hot?	☐	CG Verified?	☐
Receiver Pack Charged?	☐	Wing Securely Attached?	☐
Receiver On?	☐	Landing Gear Solid?	☐
Connection Secured?	☐	Top Lid Secured Shut?	☐

Figure 7.5: Pre-Flight Checklist

Final Checklist

The following checks are performed immediately before the aircraft's takeoff [4].

Final Checklist			
Propulsion		**Signatures**	
Receiver Connection?	☐	Pilot	______________
Control Surfaces Responsive?	☐	Faculty Advisor	______________
Telemetry Software On?	☐	Project Manger	______________
Visual Inspection	☐	Date	______________

Figure 7.6: Final Checklist

Section 8: Performance Results

8.1 Component and Subsystem Performance

Batteries

During the propulsions testing, it has been found that the battery's capacity is not as high as was predicted. This is likely due to increased thermal resistance over the course of its use. To account for this discrepancy, heat exchangers are being investigated to try and cool down the battery pack to prevent overheating. This is seen as being especially important to adjust before competition, as Tucson can be very hot in April, which could lead to catastrophic failure should the battery over heat in the hot weather.

Motor

The Scorpion 3026 V2 has been tested on a prototype plane and showed that it had enough thrust for the plane to take off within 9 feet, within the maximum 10 feet given for takeoff from the ramp. However, multiple complications with stability have prevented full testing mid-air yet. The most recent of these attempted test flight issues was likely due to an unforeseen failure in the landing gear during takeoff. This was due more to the gravel airfield that the test flight was occurring on than the performance of the motor. Static tests have revealed that the motor provides the necessary thrust to propel the plane near the target speed.

Fuselage and Wing

The wing and fuselage testing consisted of a process of adding weight incrementally to test the breaking point of each component. When performing the wing tip test, it was found to withstand approximately 30lbs before breaking. This was well within the range required. The fuselage test showed that it was even stronger, being able to support close to 35lbs of weight. Both tests have led to the team investigating ways to remove excess structural support to save on weight.

Landing Gear

The landing gear was tested statically by loading it with increasing weight until it failed. It was found to support enough load to withstand impact. However, this was when testing occurred on the independent component. during a recent test flight, the bolts securing the landing gear to the fuselage sheared the carbon fiber composite at its base. As a result, the team is currently investigating methods of further supporting the landing gear at the fuselage.

Prediction Comparisons and Improvements

Tests conducted so far have resulted in a fulfillment of the minimum requirements set out, providing a good basis for the final plane. However, as to date, there has not been a complete flight of the second prototype due to unforeseen complications. Therefore, more testing will need to be conducted to determine the full capabilities of the aircraft.

8.2 Complete Aircraft Performance

Prediction Comparisons and Improvements

Because there has yet to be a fully completed test flight, the actual flight parameters have not been evaluated yet. More testing will need to be completed to fully characterize the plane's capabilities. However, from the static load tests and motor tests, the team is fairly confident that the final plane will be close to the goals set out in the initial design phase. Once a complete test flight has been achieved, improvements to weight drag and stability can be characterized and implemented into the final design.

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