The City College of New York

The City College of New York (CCNY) of the City University of New York

AIAA 2019-2020 Design Build Fly (DBF) Proposal

Team Name: The Towing Company

1.0 Executive Summary

This proposal presents the City College of New York's design, manufacturing, and testing plan for the 2019-2020 AIAA Design, Build, Fly (DBF) competition. Our team name is The Towing Company, and our aircraft name is Brolic Beaver. Our objective is to design, build, and test a banner towing bush plane that provides charter flights, and maximizes our final score for this year's competition. The aircraft must have a maximum wingspan of five feet, remotely deploy and release a banner with a minimum length of ten inches and a maximum aspect ratio (AR) of five, and be able to takeoff within 20 feet. To maximize our final score, we conducted a scoring analysis, which suggested that maximizing the banner length and minimizing the number of passengers and pieces of luggage carried, will secure us the highest final score. Brolic Beaver will be a monoplane, powered by a single motor with a conventional tail. It will tow a 70-inch banner, carry one passenger and one piece of luggage. With these aircraft configurations, we believe we can complete the Ground Mission (GM) and Mission 2 (M2) with competitive time, and secure a high Mission 3 (M3) score.

To achieve our objectives, we will split into eight teams, which will work together to iterate the design, testing, and fabrication phases of the project. Subsequent sections discuss our team structure, projected budget, and approach to our scoring analysis and conceptual design. Additionally, we will discuss our anticipated manufacturing and testing plans for the year ahead.

2.0 Management Summary

2.1 Organization

Our organizational structure for the 2019-2020 CCNY DBF project consists of the Faculty Advisor, Chief Engineer, Team Management, and eight major functional groups shown in **Figure 1**. The faculty advisor actively monitors the team's progress, providing feedback as needed. The chief engineer shall oversee the teams' progress, provide technical input, and aid in making critical decisions throughout the year. The team management, comprising the project manager and treasurer shall work with the chief engineer to provide logistical support and ensure the team remains on or ahead of schedule and under budget. Lastly, each of the eight functional groups have (a) leader(s) to effectively manage and streamline the goals for the project. The responsibilities associated with each of those eight major groups are as follows:

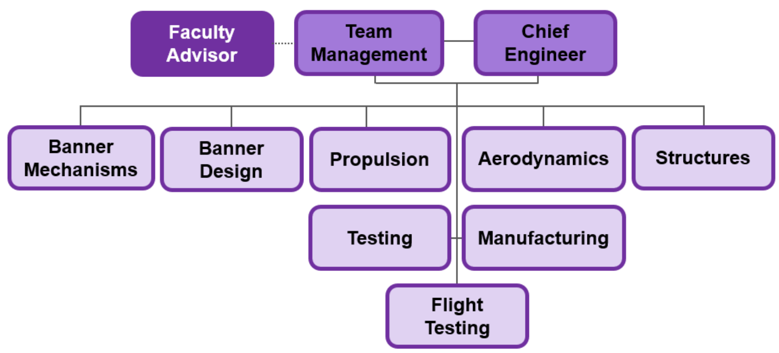

Figure 1: *AIAA DBF 2019-2020 Organizational Chart*

- **Aerodynamics:** Determine aircraft sizing; conduct Computational Fluid Dynamics (CFD) analysis and design trade studies on aircraft components using ANSYS Fluent and AVL to optimize and validate aerodynamic efficiency, aircraft stability, and control.
- **Propulsion:** Research and analyze different battery, motor, propeller, and electronic speed controller (ESC) configurations. Conduct static and wind tunnel thrust testing on candidates for final selection.
- **Structures:** Design and model the structure of the aircraft and its components based on research, engineering judgment, Finite-Element Modeling (FEM), and testing.

- **Banner Design:** Research, prototype, and test different banner configurations to observe overall performance, and ensure that mission requirements are met.
- **Banner Mechanisms:** Develop, prototype, and test mechanical designs of the banner release and deployment mechanisms.
- **Manufacturing:** Coordinate across teams (e.g. structures, propulsion, aerodynamics, mechanisms) to develop a manufacturing procedure for the aircraft. Select manufacturing techniques and technologies.
- **Testing:** Verify and validate prototype designs by testing at the component and assembly levels to improve future design iterations of Brolic Beaver.
- **Flight Testing:** Verify and validate aircraft prototype airworthiness by recording flight data. Analyze the data to ensure flight mission requirements are met, and improve on the design of future prototypes.

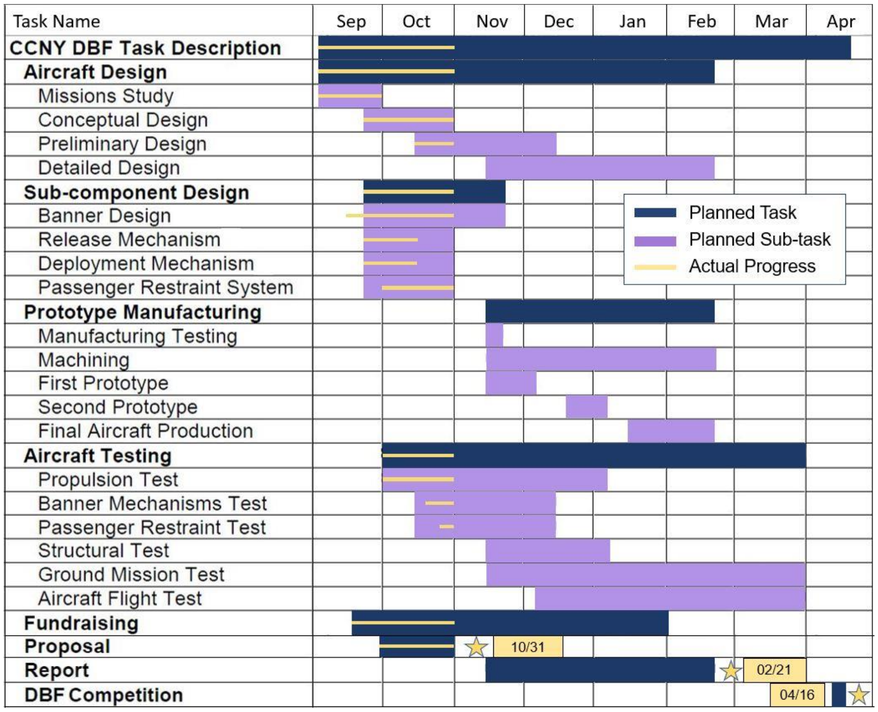

Figure 2: *Milestone Chart*

2.2 Schedule/Major Milestone Chart

A Gantt chart shown in **Figure 2** was created to establish the project path and set deadlines critical to the completion of the project. The Gantt chart shall be updated weekly to track the progress of the team's goals.

2.3 Budget and Funding

Our main funding sources are the Grove School of Engineering, the Undergraduate Student Government, and the Auxiliary Enterprise Government at CCNY, donating $5,500, $2,000, and $2,000 respectively. In addition, our treasurer is pursuing different funding strategies to increase our budget including writing sponsorship proposals to alumni, school engineering departments, and companies. This year, we expect to raise around $1,000 from fundraising events.

<table>
<tr><th></th><th colspan="2">Item</th><th>Cost</th></tr>
<tr><td></td><td colspan="3">General/Manufacturing Materials</td></tr>
<tr><td rowspan="9">Aircraft</td><td colspan="2">Materials (Carbon Fiber, Balsa Wood)</td><td>$800</td></tr>
<tr><td colspan="2">Epoxy, 3D Filament, Monokote</td><td>$300</td></tr>
<tr><td colspan="2">Banner Fabric, Nylon Thread, Fishing Wire</td><td>$135</td></tr>
<tr><td colspan="2">Raw Material (Aluminum, Tubes, etc.)</td><td>$100</td></tr>
<tr><td colspan="2">Fuses, Connectors, Wires, etc.</td><td>$75</td></tr>
<tr><td colspan="2">Screws, Hinges, Push Rods, Control Horns</td><td>$95</td></tr>
<tr><td colspan="2">Power Tools + Supplies</td><td>$400</td></tr>
<tr><td colspan="2">College Resource (e.g. Laser Cutter)</td><td>$100</td></tr>
<tr><td colspan="2">Landing Gear/Wheels</td><td>$100</td></tr>
<tr><td rowspan="3">Propulsion & Electronics</td><td colspan="2">Motors (Up to 3) & Propellers</td><td>$765</td></tr>
<tr><td colspan="2">LiPo Batteries (Up to 5 Packs)</td><td>$725</td></tr>
<tr><td colspan="2">Transmitter, Speed Controllers, Receiver, and Servos/Mechanisms</td><td>$600</td></tr>
<tr><td>Testing</td><td colspan="2">Sensors, Data Acquisition Systems</td><td>$350</td></tr>
<tr><td>Safety</td><td colspan="2">Safety Supplies</td><td>$500</td></tr>
<tr><td rowspan="5">Travel Expenses</td><td colspan="3">Traveling & Lodging</td></tr>
<tr><td>QTY.</td><td>Category</td><td></td></tr>
<tr><td>2 Rooms | 7 People (5 Nights)</td><td>Hotel</td><td>$850</td></tr>
<tr><td>-</td><td>Gas</td><td>$400</td></tr>
<tr><td>-</td><td>Travel Incidentals</td><td>$200</td></tr>
<tr><td></td><td></td><td>Total</td><td>$6,495</td></tr>
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Table 1: *Estimated 2019-2020 Budget*

Regarding the transportation to the competition, the team will be traveling to Wichita, Kansas in three student-owned cars. The aircraft will be disassembled and stowed in one of the cars to reduce space and prevent potential damage. After considering last year's financial data and researching this year's expected expenses, we estimated the following budget in **Table 1**.

3.0 Conceptual Design Approach

3.1 Mission Requirements

As specified by this year's DBF rules, the objective of the competition is to design a banner towing bush plane able to conduct charter flights, and complete four missions. Each mission has different requirements, which are summarized in **Table 2.** Additionally, the mission requirements are divided into different sub-system requirements.

Mission Score		Requirements	Sub-System Requirements
Ground Mission	**Ground Mission (GM)** $GM = \frac{Min_{time}}{N_{time}}$	• The installation and removal of the passengers and pieces of luggage inside the aircraft will be timed; the installation of the banner in the stowed configuration onto the aircraft will be timed. • The pilot must demonstrate deployment and release of the banner.	• Develop an easily accessible passenger and luggage restraint system. • Research and test efficient deployment and release mechanisms for the banner.
Flight Missions	**Mission 1 (M1): Test Flight** $M_1 = 1$	• The unloaded aircraft must complete 3 laps within 5 minutes. • The aircraft must takeoff within 20 feet.	• Minimize the stall speed to assist with takeoff. • Select a banner configuration that has a low coefficient of drag. • Design robust mechanisms that deploy and release the banner successfully during flight. • Select a propulsion system that has high thrust to counter drag induced by the banner, and sufficient pitch speed to complete a competitive number of laps within the given time constraint. • Use a high-pitch propeller for M2 for competitive lap time.
	Mission 2 (M2): Charter Flight $M_2 = 1 + \frac{N_{pass}/N_{time}}{Max_{pass}/Max_{time}}$	• The loaded aircraft with passengers and pieces of luggage must complete 3 laps within 5 minutes.	
	Mission 3 (M3): Banner Flight $M_3 = 2 + \frac{N_{\#laps} * N_{len_{banner}}}{M_{\#laps} * M_{len_{banner}}}$	• The aircraft must takeoff within 20 feet. • The minimum length and aspect ratio of the banner are ten inches and five, respectively. • The banner must be deployed and remain in the vertical orientation during flight. • The banner must be released after the aircraft crosses the finish line on the last lap. • The mission must be completed within 10 minutes.	

Table 2: *Decomposed Requirements*

3.2 Scoring Sensitivity Analysis

We approached the scoring analysis by examining which scoring parameters should be prioritized in order to maximize the final score. Based on initial propulsion research, banner wind tunnel testing, and general aircraft knowledge, we correlated the scoring parameters using empty weight, drag, and thrust. For example, an increase in the number of carried passengers and pieces of luggage leads to an increase in loading time for the GM, an increase in empty weight, and an increase in drag, constraining the banner length for M3.

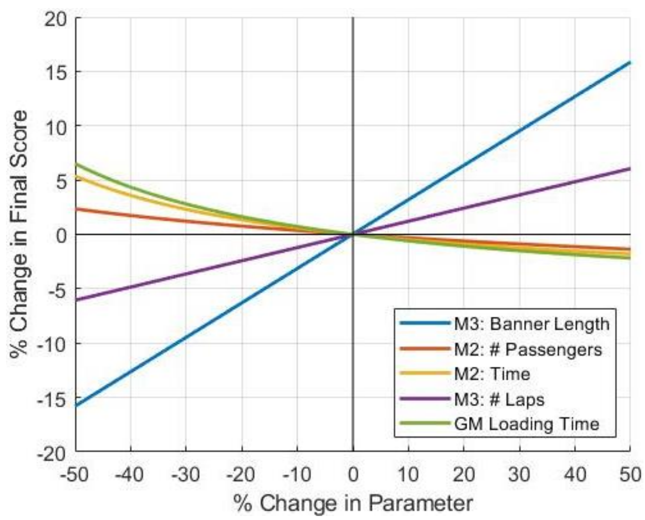


Figure 3: *Scoring Analysis of Mission Parameters*

Based on the correlation established, the percent change in the final score was plotted against the percent change in each parameter as shown in **Figure 3**. Since the slope relating the banner length to the final score is the steepest, and the final score decreases as the number of passengers and pieces of luggage increases, maximizing the banner length and minimizing the number of carried passengers and pieces of luggage will earn us the highest final score.

3.3 Preliminary Design, Sizing, and Our Design Approach

Based on the results of the scoring analysis, we aim to build an aircraft which will tow a large banner, complete M2 in competitive time with one passenger and one piece of luggage, and allow us to achieve an optimal GM score. In order to tow a large banner, the propulsion system must produce high thrust to counter the banner induced drag. This calls for a motor with high torque, a large diameter propeller, and high capacity LiPo battery cells to last the duration of M3.

Figure 4: *Conceptual Solid Model*

Knowing that high thrust comes at a price of extra propulsion weight, and knowing that traveling at a low velocity will induce less banner drag, we aimed to minimize the stall velocity of the aircraft. This led us to select a high lift airfoil, use the maximum allowable wingspan, and have the wing at a constant angle of attack (AOA). The low stall velocity as well as thrust vectoring will assist with the 20 ft takeoff. Considering the tradeoff between wing surface area and pitch stability, we chose to limit the aspect ratio of the wing to seven.

We approached the sizing of the banner by testing various designs in a wind tunnel to quantify the induced drag. Using the C_d range obtained from testing (0.1 – 0.15), a MATLAB code was written to optimize the banner length and aircraft velocity since they are dependent on one another. The code simulates the aircraft in-flight with different banner lengths and propulsion systems. It sums the forces acting on the aircraft including the drag force induced by the banner, and ensures the aircraft has enough thrust, lift, and energy to complete the course maneuvers. The code suggests that the longest banner we can successfully tow is 70 inches with an aspect ratio of five while traveling at a maximum speed of 51 feet/sec.

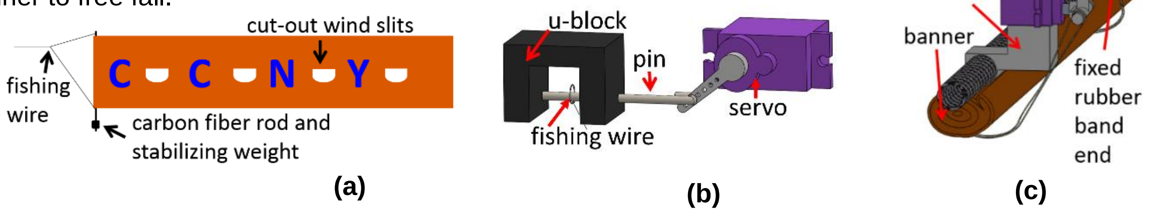
Furthermore, we aim to increase the aerodynamic efficiency of the aircraft by minimizing the volume of the fuselage, while still allowing easy access to the passenger and luggage to optimize the GM loading time. The resulting conceptual design is shown in **Figure 4**. Our preliminary aircraft sizing and anticipated mission targets are shown in **Table 3.** These results are a product of the thought process explained above.

	Wing	Horizontal Stabilizer	Vertical Stabilizer
Span	60 in	20.08 in	12.05 in
Chord	8.57 in	5.02 in	5.02 in
Aspect Ratio	7	4	2.4
Surface Area	514 in^2	100.82 in^2	60.49 in^2
Airfoil Candidate	SD7062	NACA 0010	NACA 0010
% Chord	25% (Flaps/Aileron)	30% (Elevator)	30% (Rudder)
Banner Sizing		Estimated Mission Performance	
Banner Length	70 inches	M3: # of Laps	6
Banner AR	5	M2: Time	100 seconds

Table 3: *Initial Sizing Results and Mission Targets*

The banner design, deployment and release mechanisms are shown in **Figure 5**. The banner will be rolled up and stored via elastic bands that are fixed on one end of the servo mount, loop around the banner and boom tail, and hook on to the servo control horn (**Figure 5c**). Once the servo rotates, the elastic bands release, deploying the banner. The banner itself will have fishing wire that hooks onto the release mechanism placed at the aircraft's center of gravity. This mechanism consists of a pin attached to a servo, secured between a u-block (**Figure 5b**). Once the servo rotates the pin will move out of the u-block, releasing the fishing wire, and allowing the banner to free fall.

Figure 5: *(a) Banner Design; (b) Banner Release Mechanism; (c) Banner Deployment Mechanism*



4.0 Manufacturing Plan

Figure 6 shows our manufacturing flow chart. The banner will be made of ripstop nylon, sewn with nylon thread and cotton-polyester thread on a Singer Prelude 8280 machine. The passenger and piece of luggage will be 3D printed at 100% density. To achieve the weight specified in the rules, a strong magnet will be installed in each passenger and piece of luggage; the magnet will act as a restraint system since the 3D printed restraint base will also have a magnet (**Figure 7**). The banner deployment and release mounts will also be 3D printed. The fuselage will be manufactured by vacuum bagging plain weave carbon fiber. The mold used for vacuum bagging will be 3D printed to ensure symmetry, and to accurately capture the aerodynamic geometry of the fuselage. The landing gear will also be manufactured by vacuum bagging unidirectional tape; the plies will be symmetric and balanced to avoid springing. We will use the balsa build-up method to manufacture the wing and empennage by aligning laser cut ribs along a carbon fiber tube. Monokote will cover the entire wing and empennage. An adapter will be 3D printed to connect the wing's main carbon fiber tube to the boom tail and the banner release mechanism. The wing will have a second, thinner, parallel carbon fiber tube of shorter length towards the aft end. This will connect to the boom tail to act as a secondary support.

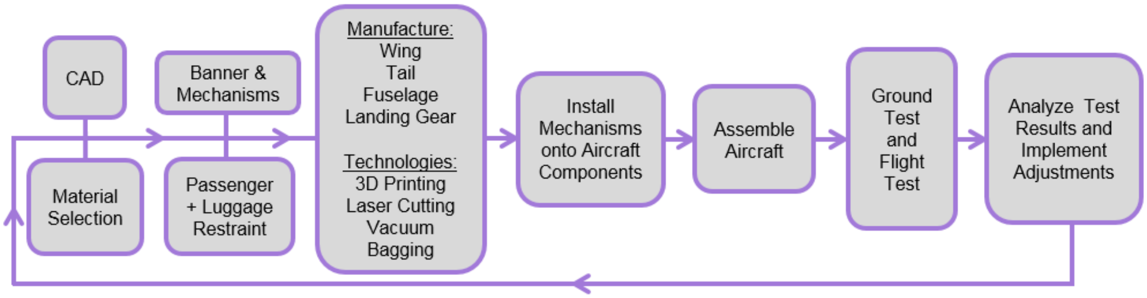


Figure 6: *Manufacturing Flow Chart*

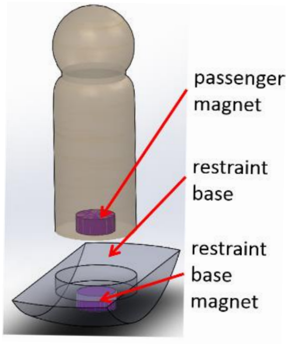


Figure 7: *Passenger Restraint System*

5.0 Testing Plan

This year we will be conducting component, ground mission and flight testing. For propulsion, we will conduct static and wind tunnel testing on different battery/motor/propeller/ESC configurations to test the thrust, pitch speed, energy consumption, efficiency, and endurance. Testing data will be used to select a final propulsion configuration. Different banner designs will be tested in a wind tunnel under different wind conditions to quantify the induced drag and observe banner stability. Different banner designs will include varying the material, length, aspect ratio, location and quantity of wind slits, stabilizing weights, and reinforcing rods. Data collected will be analyzed to select the design with the lowest C_d without sacrificing stability. Wind tunnel testing will be conducted on the banner deployment and release (D&R) mechanisms to validate functionality. For structural testing, we will drop test landing gear with simulated plane weight, and conduct wingtip tests to simulate g-forces acting on the wings. For ground mission testing, loading the fuselage and mounting the banner to the deployment mechanism will be timed.

Test	Dates
Propulsion	10/1 - 1/15
Landing Gear	11/1 - 11/15
Banner Design	9/15 - 11/15
Banner D&R	11/15 - 1/15
Structural	11/15 - 1/15
Ground Mission	11/15 – 3/31
P1 Flight Test	12/6 - 12/15
P2 Flight Test	1/6 - 1/15

Table 4: *Testing Schedule*

For flight testing, we will build two prototypes (P1 and P2) and conduct test flights for each. We will test flight performance by outfitting the aircraft with multiple sensors (altitude, amperage, G force, and GPS). Additionally, we will verify that the aircraft takes off within 20 feet, D&R mechanisms are functional, banner remains vertical, and verify the plane's structural integrity when turning. Flight Mission 2 will be timed, and the number of laps completed in M3 will be recorded to assess competitive performance. The data collected from sensors and observations made by the flight testing team and pilot will be analyzed to improve the design of future prototypes. **Table 4** shows our testing schedule.

1. Executive Summary:

This proposal aims to embody the design, analysis and manufacturing of the aircraft designed by Team Aeolus, the aeromodelling and aerial robotics team of **PES University,** for the 2019-2020 AIAA Design, Build and Fly competition.

The objectives set for this year are to design, build and test a charter aircraft that can provision the towing of a banner. The aircraft can have a maximum wingspan of five feet, in addition, the aircraft must fly with its banner deployment, towing and release mechanisms primed for all missions. The aircraft would also carry a few 4-ounce passengers and a 1-ounce luggage accompanying each passenger in order to simulate the charter characteristics of the aircraft. A banner must be remotely deployed in flight, retain its vertical orientation and be remotely released from the aircraft, the critical points here are that the required mechanism and the banner itself must be light enough to maximize the number of laps and unfurl behind the aircraft but at the same time have enough weight to maintain stability during flight.

In order to better understand and analyse the scoring system, a score sensitivity analysis was performed, and it was concluded that apart from the design report, the number of passengers being transported in the second mission and the size of the banner in the third mission are the most effective scoring parameters, and hence the entire design process was focused on maximizing these particular parameters. Accordingly, the team came up with a design for this year's edition, which is a single motor, propeller driven, tail dragger for housing the unfurled banner, modified empennage to house the banner unfurling and release mechanisms, and a large payload fraction, designed to carry 12 passengers.

2. Management Summary:

2.1. Organisation Summary:

The participating team comprises of a faculty in charge, a team leader, a treasurer and 10 Undergraduate students. The faculty in charge monitors the progress of the team and provides necessary guidance and advice on consultation. The team leader takes a final call on all the decisions considered by the team and is responsible for maintaining the team's schedule. The team leader, treasurer and 10 working members are further divided into sub-teams for the efficient functioning of the team. Each member submits reports on the tasks assigned to and completed by him and any queries, or difference in opinions that arise from the actions taken by the members are discussed and a final verdict is delivered by the team leader. The treasurer keeps track of team funds and ensures efficient usage of the same. The sub-teams along with their objectives and skill requirements are mentioned in **Table 2.1**.

Sub – Team	Objective	Skill requirements
Documentation	• Drafting/Formatting the proposal and design report	• Writing skills • Technical knowledge
Aerodynamics	• Aerodynamic calculations to find ideal stability and performance	• Aerodynamics Fundamentals • XFLR5 & MATLAB software skills
Modelling and Design	• Designing and modelling the aircraft structure on software aids	• Knowledge regarding drafting • Good grasp on DS SOLIDWORKS
Fabrication	• Manufacturing of the designed parts and their assembly	• Tool handling • Assembly knowledge
Analysis	• Structural tests and flow simulations to validate the work of Aerodynamics and design sub – teams.	• Structural Analysis knowledge • Using FEA tools like Ansys, Altair Hypermesh and Simscale
Propulsion	• Selection of motors and batteries for flight time considered, and optimal thrust to weight ratio.	• Propulsion system knowledge • Knowledge of eCalc: for battery - motor - propeller calculation.
Marketing	• Pitching ideas to potential investors, fundraising and advertising.	• Communication/Presentation skills

Table 2.1: Sub – Teams, their roles and skill requirements

2.2. Team Structure:

The team follows the hierarchy as represented in **Figure 2.1** in addition to this, multidisciplinary work is carried on to meet the team deadlines.

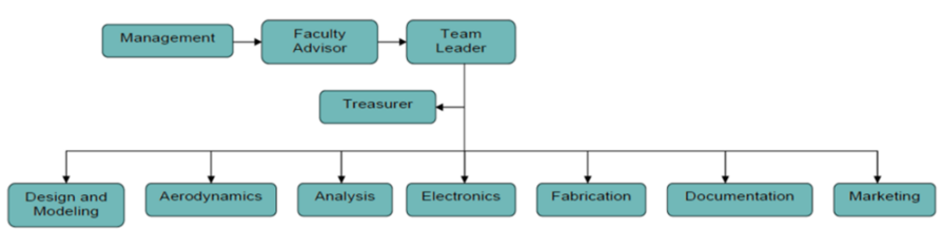


Fig 2.1: Team structure flow chart

2.3. Schedule:

A schedule was drawn to assign deadlines to each sub objective that was identified by the sub – teams and the entire team in general. This schedule is described in **Figure 2.2** as a Gantt chart.

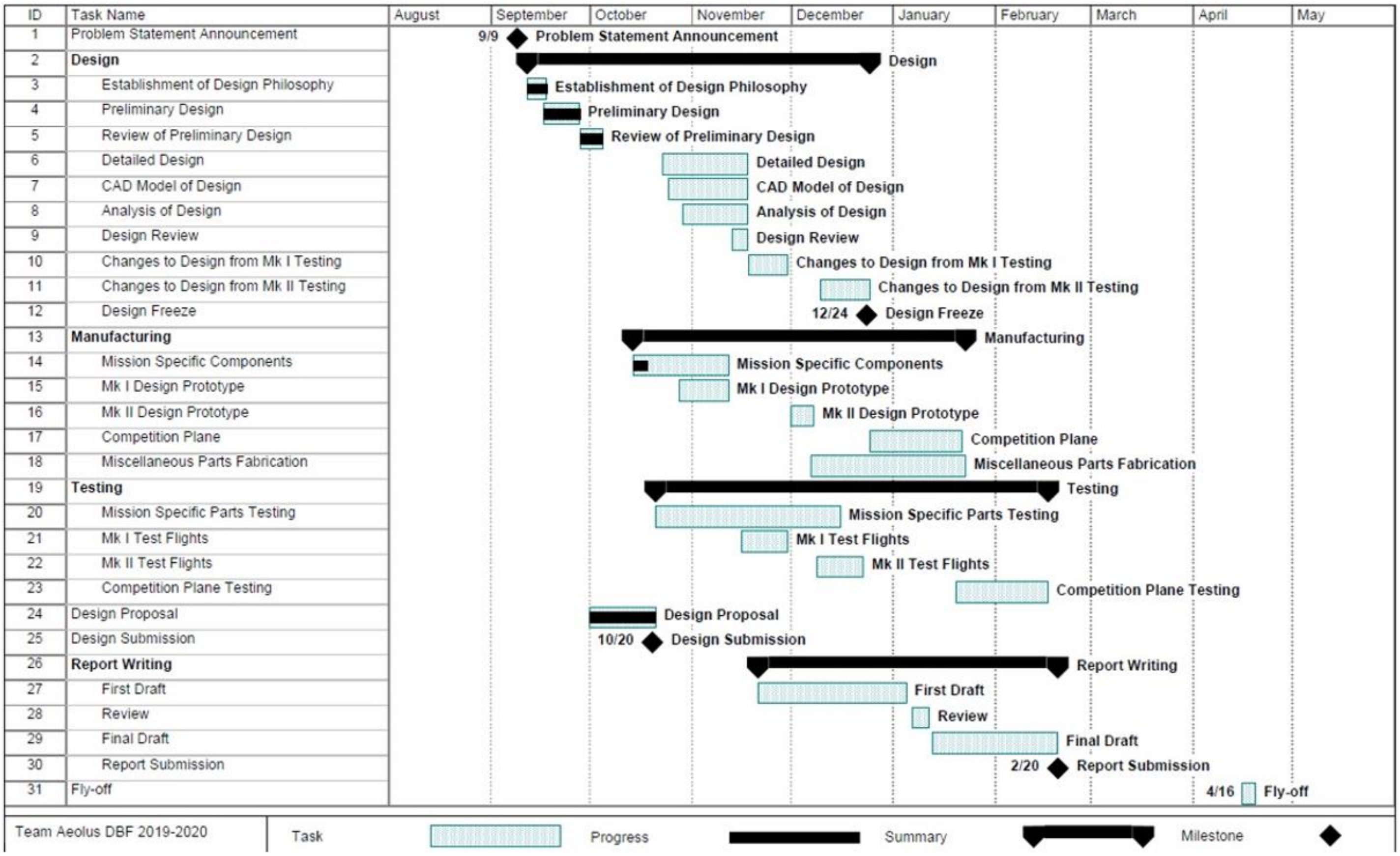


Fig 2.2: Gantt Chart

2.4. Finances:

Based on the expenses incurred during the team's previous participations and adjusting for inflation, a budget was set by the treasurer. This is represented in **Table 2.2**.

Team Aeolus is primarily funded by PES University. In addition to these funds, the marketing sub - team is actively on the lookout for procuring supplementary funds through national and International sponsorship channels.

Concerning	ID	Materials	Quantity	Cost
Aircraft	1	Carbon Fiber Reinforced Rods	-	$150
	2	Balsa Wood Sheets	-	$200
	3	Monokote	-	$125
	4	Brushless Motors/Propellers	3	$200
	5	Servo Motors	5	$30
	6	Transmitter-Receiver	1	$200
	7	LiPo Battery	5	$300
	8	ESC	3	$150
	9	Banner	2	$200
	10	Miscellaneous	-	$300
		Subtotal		**$1,855**
Transportation	1	Round Trip Ticket Price Per Person	-	$1,400
	2	Accomodation Per Person	-	$400
	3	Aircraft Shipping and Custom Duties	-	$500
		Subtotal for 10 Team Members		**$18,500**
		GRAND TOTAL		**$20,355**

Table 2.2: Budget Table

3. Conceptual Design Approach:

3.1. Problem Statement Analysis:

As per this year's rules, the objective is to design, build and test a banner towing bush plane, that is also capable of ferrying passengers and their luggage, emulating a charter plane. In addition to the three flight missions, the plane must also possess a maximum allowable wingspan of 5 feet. The airplane must carry all the additional mechanisms required for the different missions in every flight mission. The team must assemble the payload, their restraints and set up the banner mechanisms within 5 minutes.

Table 3.1 dissects the problem statement to design requirements as well as the team's approach to meet them. The team considers Tech-inspection to be an integral aspect of the competition. Appropriate testing will be done to ensure positive results.

Mission		Design Requirements	Team's approach to solve
Ground Mission		1. Adding/Removing the payload i.e., the passengers and luggage in a short time 2. Attaching/removing banner without removing/altering the mechanisms	1. Easily accessible fuse openings through which payload along with restraints can be added/removed 2. Designing mechanism with simple locking mechanisms
Flight Missions	M1	1. Complete 3 laps within 5 minutes while in unloaded condition 2. Take off within 20 ft	1. Choosing a good airfoil to ensure take-off within 20 ft as well short flight times.
	M2	1. Plane with max payload must complete 3 laps in 5 minutes.	1. Maximising payload while ensuring fast and stable flight.
	M3	1. Banner deployment and release at appropriate times. 2. Max no. of laps within 10 minutes 3. Ensure banner AR 5	1. Simple and efficient mechanism for banner deployment and release 2. Choose a banner length such that score is maximised without compromising on speed and stability.

Table 3.1: Problem Statement Analysis

Parameter	Results
Main Body	
Empty weight of Aircraft	7.72 lbs
Total weight of Aircraft	11.02 lbs
Wing dimensions	
Chord Length	10 inches
Wingspan	60 inches
Wing Aspect Ratio	6
Wing Area	4.036 $(ft)^2$
Wing Loading	2.73 lbs/ $(ft)^2$
Payload	
Number of Passengers	12
Location	Centreline of fuse
Banner Mechanism	
Location	Below the empennage

Table 3.2: Sizing Results

3.2. Preliminary Sizing Results:

Using **Table 3.1**, the team agreed on a set of dimensions for a prototype design to be the most suitable. In lieu of this, **Table 3.2** has been constructed to denote these dimensions.

3.3. Concept and Mechanism Sketches:

3.3.1. Airfoil Selection:

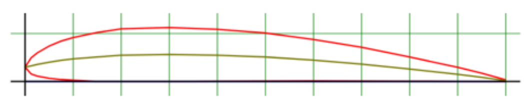


Fig 3.1: N-10 Airfoil

The primordial and pertinent step in the designing process was to decide upon the airfoil, which would play a vital role in achieving optimal flight. After much deliberation, the team decided on the flat-bottomed N-10 airfoil. N-10 turned out to have higher lift at cruise angle of attack for Reynolds number greater than 60000. The corresponding lift at stall angle is higher which provides an advantage of easier banking while executing the missions. In addition to better gliding characteristics, its flat bottom helps in ease of manufacturing.

3.3.2. Payload Configuration and Restraint System:

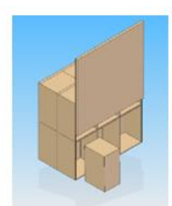


Fig 3.2: Luggage Restraint with Luggage

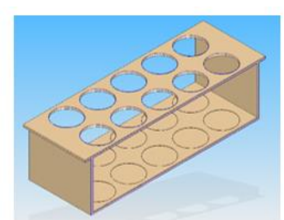


Fig 3.3: Passenger Restraint System

Working within the confines of the passenger and luggage restraint restrictions, the team decided to design two separate restraint systems – one for the passengers and one for the luggage. The passenger restraint system is a tray whose topmost plane is laser cut to the dimensions of the passengers. Guide rails are machined in the hollow part of the fuselage to seat both the passenger and luggage restraint systems. An outline of the cut – out in the fuse for this purpose is given in **Fig 3.6.** Rails are given on the sides of the passenger trays to allow them to slide in and out of the fuselage guides with ease. **Fig 3.3** describes Passenger restraint system. The same solution is applied to the luggage system also. From the team's interpretation of the rules, it was concluded that while all passengers must be in a single plane the same is not true for the luggage. Based on this assumption the luggage restraint system is a cupboard that has cubby holes for the luggage comparable to lockers. This allows the team to stack two or more luggage one on top of another in separate cubby holes. For easy replacement of the luggage, the cubby holes are made slightly bigger than the luggage. The luggage is restrained in the cubby holes by plates that are held in place by elastic bands. Two such cupboards are arranged back to back to optimize number of passengers/luggage transported. The luggage restraint system is described in **Fig 3.2**.

3.3.3. Banner Unfurling and Release Mechanism:

This is the focus of Mission 3. Here, the required mechanism and the banner must be light enough to maximize the number of laps and unfurl behind the aircraft but at the same time have enough weight to maintain stability during flight. Towards this end, the banner is made of cloth and suitably weighted at the heading of the banner. The release mechanism works on the same principle as a door latch. The nylon string that is connected to the banner is held by the latch in place. The banner is stowed along the bottom of the fuselage and is kept furled during the initial flight sequence by strings that lie on the length of the banner. These hold the banner furled due to tension acting on the strings. At the time of release/unfurl a servo is actuated and this unlatches the string, releasing the banner. These strings connect to another release to finally drop the banner at the end of final lap. These mechanisms are demonstrated with the aid of CAD models in **Fig 3.4** and **Fig 3.5**. The aircraft in its unfurled condition is presented in **Fig 3.6**.

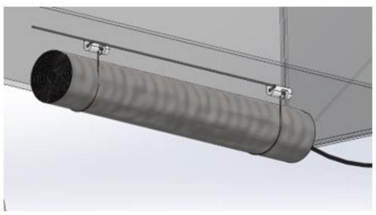


Fig 3.4: Banner Stowing Mechanism

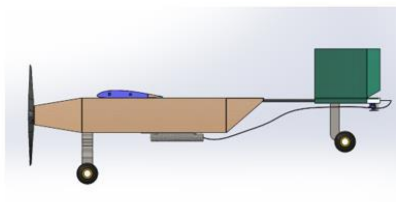


Fig 3.5: Side view of plane with banner in stowed condition

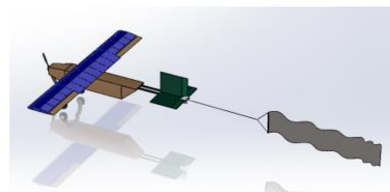


Fig 3.6: Sketch of plane with unfurled banner

The ground mission asks for a timed assembly of the stowed banner and demonstration of unfurling and release of the banner. Correspondingly, it was required that enough weight was to be attached to the banner to have a gravity assist in unfurling the banner.

3.4. Sensitivity Analysis of Scoring Parameters:

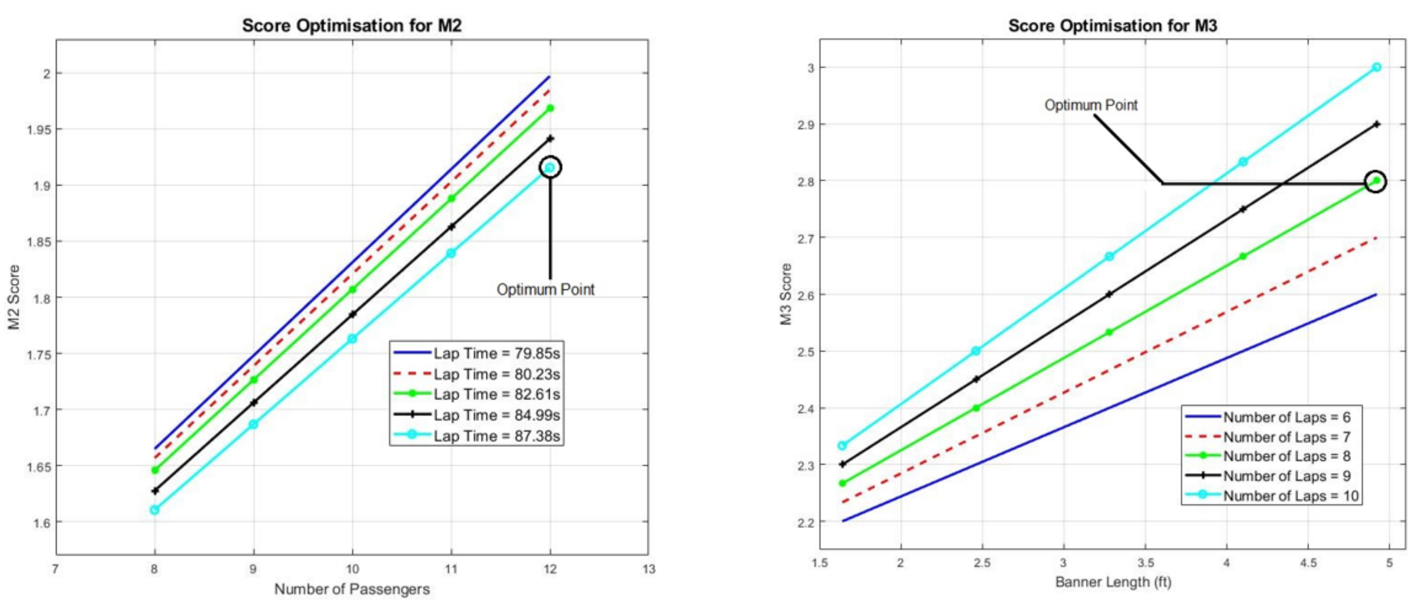


Fig 3.8: Sensitivity Analysis

A team's score is a function of the number of the passengers and the lap time in mission 2 and the total number of laps the plane can fly in each time and the length of the banner in mission 3. The maximum possible score in each mission is 2 and 3 respectively. A sensitivity analysis for the missions based on these variables was performed in order to optimize the points haul of the team. Assumptions for baseline values were made in each mission scenario. As can be seen from the graph an optimum point was selected. This point need not be the best-case scenario but must fit the team's broader design philosophy while allowing for flexibility where it is absolutely required. The optimum point is also based on what the design sub - team thinks to be an achievable target. The team has also changed its design philosophy wherever the sensitivity analysis indicates that the philosophy might be wrong.

4. <u>Manufacturing Plan:</u>

The team's manufacturing flow is represented as a flow chart in **Fig 4.1**. The team's manufacturing plan is based on iterative design. In addition to this, the team plans to test the proposed mechanisms extensively and optimize them in every prototype. Each prototype made by the team is either rapidly prototyped or formally prototyped. A rapid prototype is done to withstand expected loads during testing as proof of concept. For this type of prototype, speed and ease of manufacturing are given priority. Technologies such as 3D printing and materials such as depron are used for rapid prototyping.

Once the rapid prototype's design is finalised, it is succeeded by a formal prototype. This type of prototype prioritizes reliability and lowering weight over manufacturing feasibility. Minimal materials and intricate manufacturing steps such as laser cut balsa and composite layups are used at this stage. The component undergoes an optimization process which consists of reducing its weight until testing shows that it meets the design requirements.

While manufacturing, the team plans on using cutting edge technologies to ensure the best possible flight results. Some of the processes the team plans on using include laser cutting of balsa, rapid prototyping, hot wire cutting and composite layup. The team is planning on making the plane modular for easy assembly as well as to decrease shipping costs and difficulties; also ensuring effortless use of spares in the event of a critical failure during testing.

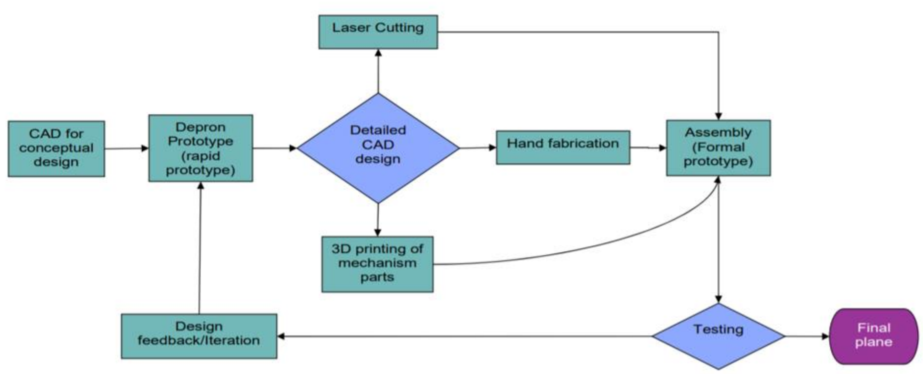


Fig 4.1: Manufacturing flow

5. <u>Testing Plan:</u>

Testing for ground mission will include timed tests to ensure quick loading/unloading of payload. It will also include testing of restraint mechanisms for passengers and their luggage by overturning the aircraft.

The team plans on conducting three prototype flights for optimising the design and operating parameters. Further, every factor affecting the aircraft will be tested based on **Table 5.1**, to ensure all desired characteristics of the aircraft are met and maintained. Through accurate testing, the team can determine any issues and adapt accordingly.

Sub – System	Component	Test Approach	Factor Checked
Propulsion	Motor and Propellers	Motor Test Stand	Efficiency and Static Thrust
	Battery		Current/Voltage draw, Battery life
Electronics	Control Surfaces	Transmitter Controls	All functions work
	Banner Unfurling/Release Mechanisms		All mechanisms are functional
Structures	Center of Gravity (CG)	Balancing the aircraft on a scale	Ensure CG is in desired location
	Wing tip loading	Bending test	Wing rigidity for flight operations
	Internal structures and restraints	Loading tests	Determine failure load and ensure it is within required limits
Flight	Speed	Timing with help of stopwatch	Lap Timing
	Stability	Visual cue and pilot's feedback	Flight Characteristics
	Range	Visual cues	Range up to which battery life calculations hold up.
			Transmitter Range
	Take – off distance	Mark take – off point	Approximate Take – off distance

Table 5.1: Testing Plan

Lastly, a test flight will be conducted with the team's actual competition plane in order to simulate all missions and to trim the aircraft for the contest.

1. Executive Summary:

This proposal aims to embody the design, analysis and manufacturing of the aircraft designed by Team Aeolus, the aeromodelling and aerial robotics team of **PES University,** for the 2019-2020 AIAA Design, Build and Fly competition.

The objectives set for this year are to design, build and test a charter aircraft that can provision the towing of a banner. The aircraft can have a maximum wingspan of five feet, in addition, the aircraft must fly with its banner deployment, towing and release mechanisms primed for all missions. The aircraft would also carry a few 4-ounce passengers and a 1-ounce luggage accompanying each passenger in order to simulate the charter characteristics of the aircraft. A banner must be remotely deployed in flight, retain its vertical orientation and be remotely released from the aircraft, the critical points here are that the required mechanism and the banner itself must be light enough to maximize the number of laps and unfurl behind the aircraft but at the same time have enough weight to maintain stability during flight.

In order to better understand and analyse the scoring system, a score sensitivity analysis was performed, and it was concluded that apart from the design report, the number of passengers being transported in the second mission and the size of the banner in the third mission are the most effective scoring parameters, and hence the entire design process was focused on maximizing these particular parameters. Accordingly, the team came up with a design for this year's edition, which is a single motor, propeller driven, tail dragger for housing the unfurled banner, modified empennage to house the banner unfurling and release mechanisms, and a large payload fraction, designed to carry 12 passengers.

2. Management Summary:

2.1. Organisation Summary:

The participating team comprises of a faculty in charge, a team leader, a treasurer and 10 Undergraduate students. The faculty in charge monitors the progress of the team and provides necessary guidance and advice on consultation. The team leader takes a final call on all the decisions considered by the team and is responsible for maintaining the team's schedule. The team leader, treasurer and 10 working members are further divided into sub-teams for the efficient functioning of the team. Each member submits reports on the tasks assigned to and completed by him and any queries, or difference in opinions that arise from the actions taken by the members are discussed and a final verdict is delivered by the team leader. The treasurer keeps track of team funds and ensures efficient usage of the same. The sub-teams along with their objectives and skill requirements are mentioned in **Table 2.1**.

Sub – Team	Objective	Skill requirements
Documentation	• Drafting/Formatting the proposal and design report	• Writing skills • Technical knowledge
Aerodynamics	• Aerodynamic calculations to find ideal stability and performance	• Aerodynamics Fundamentals • XFLR5 & MATLAB software skills
Modelling and Design	• Designing and modelling the aircraft structure on software aids	• Knowledge regarding drafting • Good grasp on DS SOLIDWORKS
Fabrication	• Manufacturing of the designed parts and their assembly	• Tool handling • Assembly knowledge
Analysis	• Structural tests and flow simulations to validate the work of Aerodynamics and design sub – teams.	• Structural Analysis knowledge • Using FEA tools like Ansys, Altair Hypermesh and Simscale
Propulsion	• Selection of motors and batteries for flight time considered, and optimal thrust to weight ratio.	• Propulsion system knowledge • Knowledge of eCalc: for battery - motor - propeller calculation.
Marketing	• Pitching ideas to potential investors, fundraising and advertising.	• Communication/Presentation skills

Table 2.1: Sub – Teams, their roles and skill requirements

2.2. Team Structure:

The team follows the hierarchy as represented in **Figure 2.1** in addition to this, multidisciplinary work is carried on to meet the team deadlines.

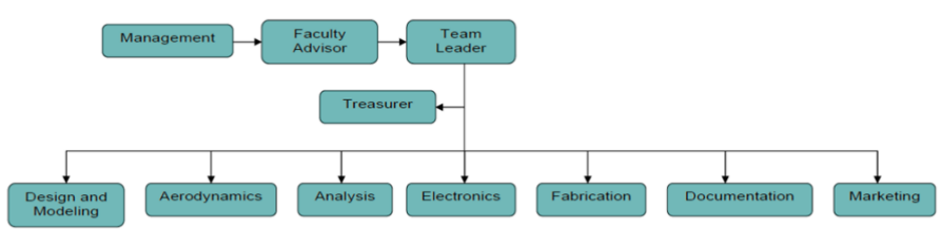


Fig 2.1: Team structure flow chart

2.3. Schedule:

A schedule was drawn to assign deadlines to each sub objective that was identified by the sub – teams and the entire team in general. This schedule is described in **Figure 2.2** as a Gantt chart.

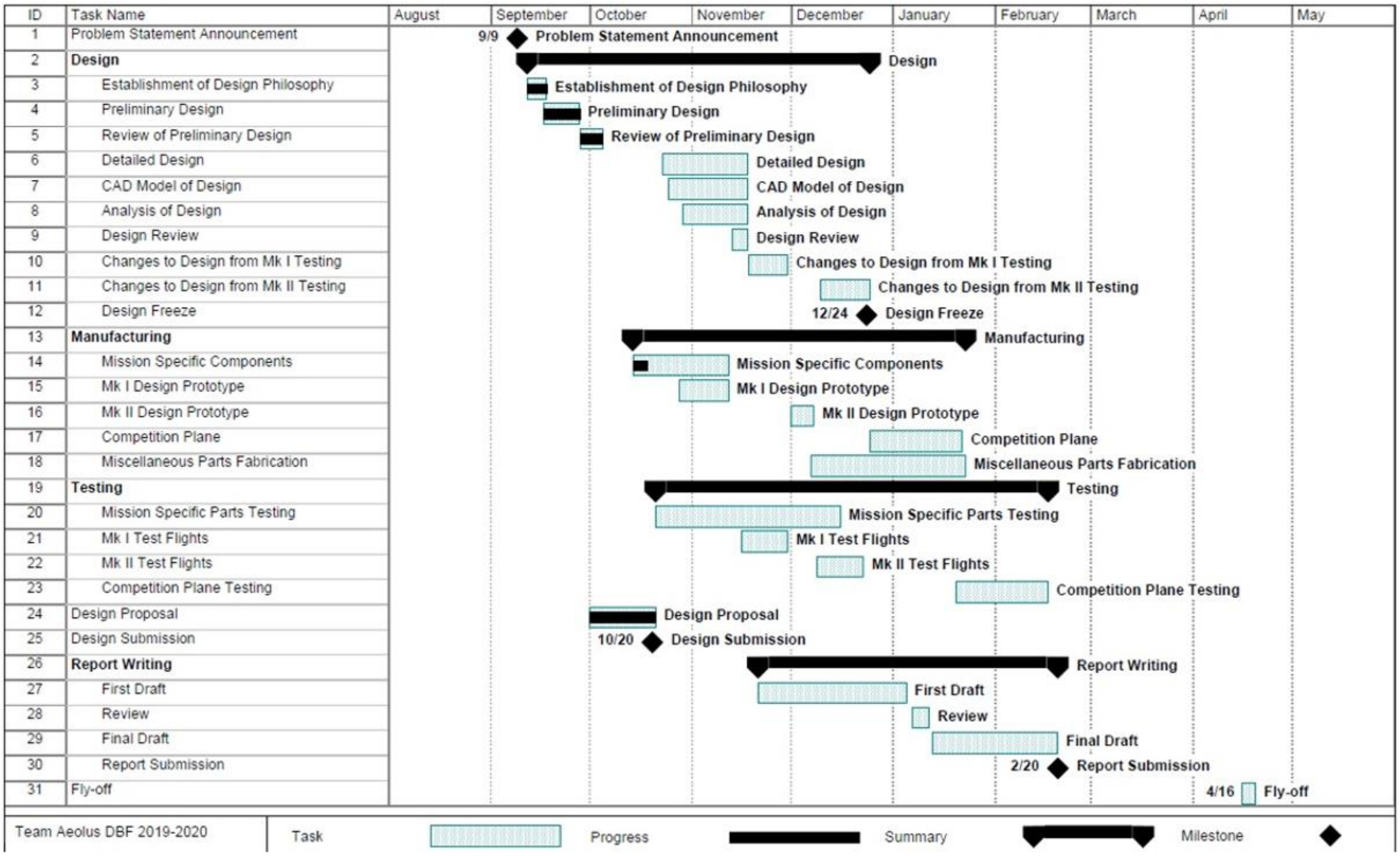


Fig 2.2: Gantt Chart

2.4. Finances:

Based on the expenses incurred during the team's previous participations and adjusting for inflation, a budget was set by the treasurer. This is represented in **Table 2.2**.

Team Aeolus is primarily funded by PES University. In addition to these funds, the marketing sub - team is actively on the lookout for procuring supplementary funds through national and International sponsorship channels.

Concerning	ID	Materials	Quantity	Cost
Aircraft	1	Carbon Fiber Reinforced Rods	-	$150
	2	Balsa Wood Sheets	-	$200
	3	Monokote	-	$125
	4	Brushless Motors/Propellers	3	$200
	5	Servo Motors	5	$30
	6	Transmitter-Receiver	1	$200
	7	LiPo Battery	5	$300
	8	ESC	3	$150
	9	Banner	2	$200
	10	Miscellaneous	-	$300
		Subtotal		**$1,855**
Transportation	1	Round Trip Ticket Price Per Person	-	$1,400
	2	Accomodation Per Person	-	$400
	3	Aircraft Shipping and Custom Duties	-	$500
		Subtotal for 10 Team Members		**$18,500**
		GRAND TOTAL		**$20,355**

Table 2.2: Budget Table

3. Conceptual Design Approach:

3.1. Problem Statement Analysis:

As per this year's rules, the objective is to design, build and test a banner towing bush plane, that is also capable of ferrying passengers and their luggage, emulating a charter plane. In addition to the three flight missions, the plane must also possess a maximum allowable wingspan of 5 feet. The airplane must carry all the additional mechanisms required for the different missions in every flight mission. The team must assemble the payload, their restraints and set up the banner mechanisms within 5 minutes.

Table 3.1 dissects the problem statement to design requirements as well as the team's approach to meet them. The team considers Tech-inspection to be an integral aspect of the competition. Appropriate testing will be done to ensure positive results.

Mission		Design Requirements	Team's approach to solve
Ground Mission		1. Adding/Removing the payload i.e., the passengers and luggage in a short time 2. Attaching/removing banner without removing/altering the mechanisms	1. Easily accessible fuse openings through which payload along with restraints can be added/removed 2. Designing mechanism with simple locking mechanisms
Flight Missions	M1	1. Complete 3 laps within 5 minutes while in unloaded condition 2. Take off within 20 ft	1. Choosing a good airfoil to ensure take-off within 20 ft as well short flight times.
	M2	1. Plane with max payload must complete 3 laps in 5 minutes.	1. Maximising payload while ensuring fast and stable flight.
	M3	1. Banner deployment and release at appropriate times. 2. Max no. of laps within 10 minutes 3. Ensure banner AR 5	1. Simple and efficient mechanism for banner deployment and release 2. Choose a banner length such that score is maximised without compromising on speed and stability.

Table 3.1: Problem Statement Analysis

Parameter	Results
Main Body	
Empty weight of Aircraft	7.72 lbs
Total weight of Aircraft	11.02 lbs
Wing dimensions	
Chord Length	10 inches
Wingspan	60 inches
Wing Aspect Ratio	6
Wing Area	$4.036\ (ft)^2$
Wing Loading	2.73 lbs/ $(ft)^2$
Payload	
Number of Passengers	12
Location	Centreline of fuse
Banner Mechanism	
Location	Below the empennage

Table 3.2: Sizing Results

3.2. Preliminary Sizing Results:

Using **Table 3.1**, the team agreed on a set of dimensions for a prototype design to be the most suitable. In lieu of this, **Table 3.2** has been constructed to denote these dimensions.

3.3. Concept and Mechanism Sketches:

3.3.1. Airfoil Selection:

The primordial and pertinent step in the designing process was to decide upon the airfoil, which would play a vital role in achieving optimal flight. After much deliberation, the team decided on the flat-bottomed N-10 airfoil. N-10 turned out to have higher lift at cruise angle of attack for Reynolds number greater than 60000. The corresponding lift at stall angle is higher which provides an advantage of easier banking while executing the missions. In addition to better gliding characteristics, its flat bottom helps in ease of manufacturing.

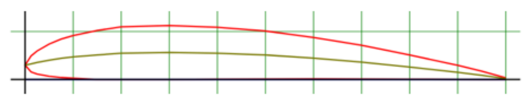


Fig 3.1: N-10 Airfoil

3.3.2. Payload Configuration and Restraint System:

Working within the confines of the passenger and luggage restraint restrictions, the team decided to design two separate restraint systems – one for the passengers and one for the luggage. The passenger restraint system is a tray whose topmost plane is laser cut to the dimensions of the passengers. Guide rails are machined in the hollow part of the fuselage to seat both the passenger and luggage restraint systems. An outline of the cut – out in the fuse for this purpose is given in **Fig 3.6.** Rails are given on the sides of the passenger trays to allow them to slide in and out of the fuselage guides with ease. **Fig 3.3** describes Passenger restraint system. The same solution is applied to the luggage system also. From the team's interpretation of the rules, it was concluded that while all passengers must be in a single plane the same is not true for the luggage. Based on this assumption the luggage restraint system is a cupboard that has cubby holes for the luggage comparable to lockers. This allows the team to stack two or more luggage one on top of another in separate cubby holes. For easy replacement of the luggage, the cubby holes are made slightly bigger than the luggage. The luggage

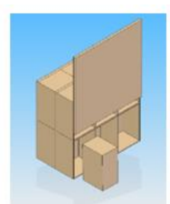


Fig 3.2: Luggage Restraint with Luggage

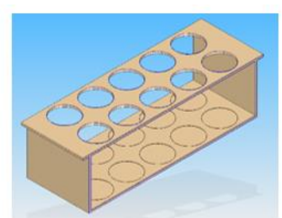


Fig 3.3: Passenger Restraint System

is restrained in the cubby holes by plates that are held in place by elastic bands. Two such cupboards are arranged back to back to optimize number of passengers/luggage transported. The luggage restraint system is described in **Fig 3.2**.

3.3.3. <u>Banner Unfurling and Release Mechanism:</u>

This is the focus of Mission 3. Here, the required mechanism and the banner must be light enough to maximize the number of laps and unfurl behind the aircraft but at the same time have enough weight to maintain stability during flight. Towards this end, the banner is made of cloth and suitably weighted at the heading of the banner. The release mechanism works on the same principle as a door latch. The nylon string that is connected to the banner is held by the latch in place. The banner is stowed along the bottom of the fuselage and is kept furled during the initial flight sequence by strings that lie on the length of the banner. These hold the banner furled due to tension acting on the strings. At the time of release/unfurl a servo is actuated and this unlatches the string, releasing the banner. These strings connect to another release to finally drop the banner at the end of final lap. These mechanisms are demonstrated with the aid of CAD models in **Fig 3.4** and **Fig 3.5**. The aircraft in its unfurled condition is presented in **Fig 3.6**.

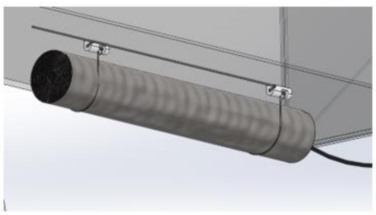


Fig 3.4: Banner Stowing Mechanism

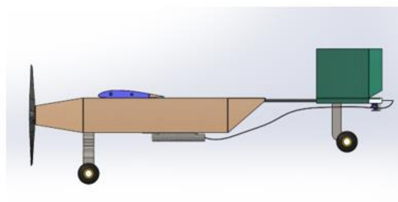


Fig 3.5: Side view of plane with banner in stowed condition

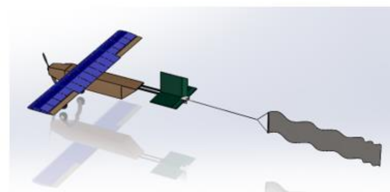
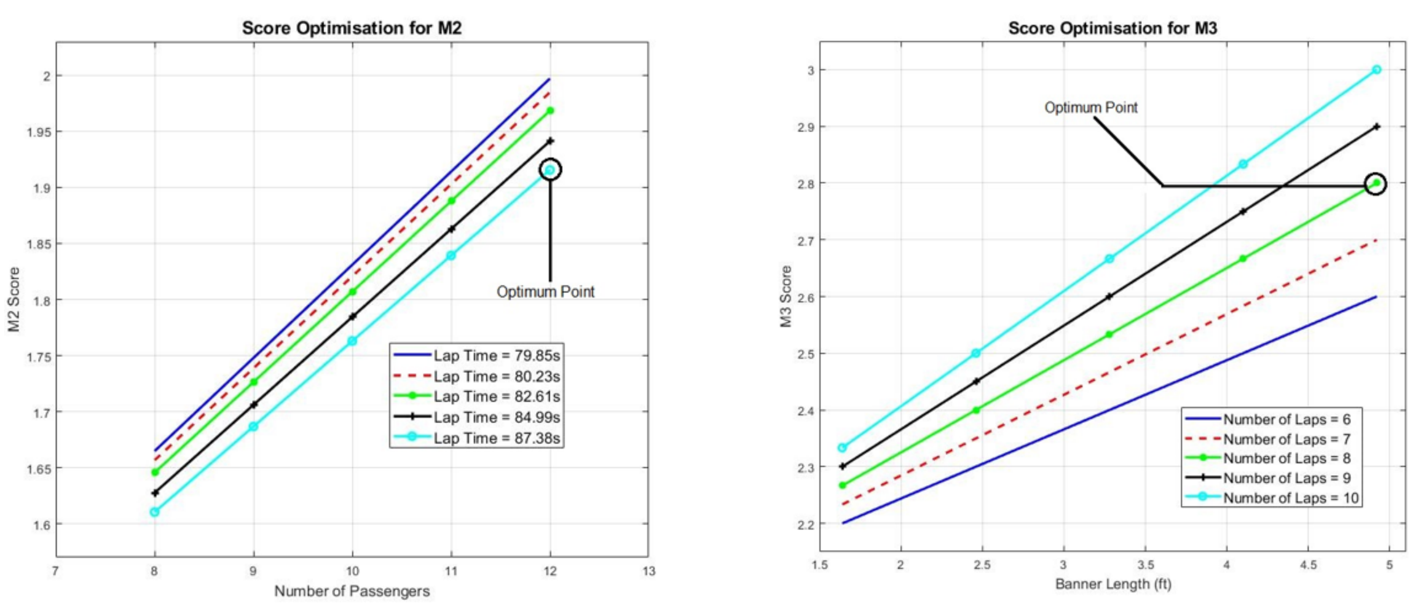


Fig 3.6: Sketch of plane with unfurled banner

The ground mission asks for a timed assembly of the stowed banner and demonstration of unfurling and release of the banner. Correspondingly, it was required that enough weight was to be attached to the banner to have a gravity assist in unfurling the banner.

3.4. <u>Sensitivity Analysis of Scoring Parameters:</u>



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A team's score is a function of the number of the passengers and the lap time in mission 2 and the total number of laps the plane can fly in each time and the length of the banner in mission 3. The maximum possible score in each mission is 2 and 3 respectively. A sensitivity analysis for the missions based on these variables was performed in order to optimize the points haul of the team. Assumptions for baseline values were made in each mission scenario. As can be seen from the graph an optimum point was selected. This point need not be the best-case scenario but must fit the team's broader design philosophy while allowing for flexibility where it is absolutely required. The optimum point is also based on what the design sub - team thinks to be an achievable target. The team has also changed its design philosophy wherever the sensitivity analysis indicates that the philosophy might be wrong.

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The team's manufacturing flow is represented as a flow chart in **Fig 4.1**. The team's manufacturing plan is based on iterative design. In addition to this, the team plans to test the proposed mechanisms extensively and optimize them in every prototype. Each prototype made by the team is either rapidly prototyped or formally prototyped. A rapid prototype is done to withstand expected loads during testing as proof of concept. For this type of prototype, speed and ease of manufacturing are given priority. Technologies such as 3D printing and materials such as depron are used for rapid prototyping.

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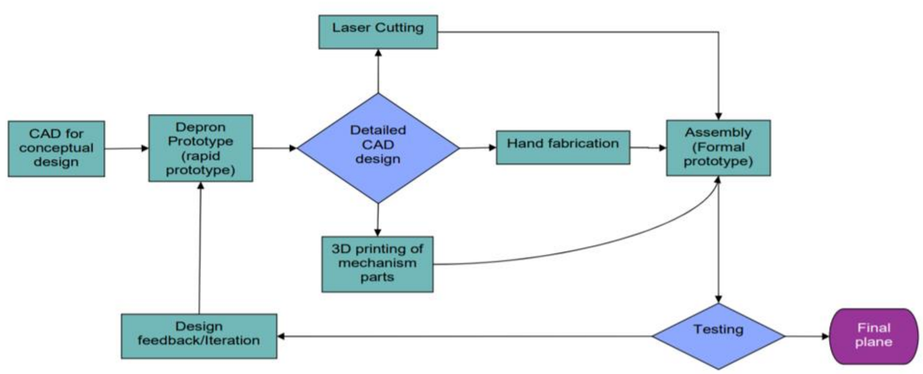

Fig 4.1: Manufacturing flow

5. Testing Plan:

Testing for ground mission will include timed tests to ensure quick loading/unloading of payload. It will also include testing of restraint mechanisms for passengers and their luggage by overturning the aircraft.

The team plans on conducting three prototype flights for optimising the design and operating parameters. Further, every factor affecting the aircraft will be tested based on **Table 5.1**, to ensure all desired characteristics of the aircraft are met and maintained. Through accurate testing, the team can determine any issues and adapt accordingly.

Sub – System	Component	Test Approach	Factor Checked
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Table 5.1: Testing Plan

Lastly, a test flight will be conducted with the team's actual competition plane in order to simulate all missions and to trim the aircraft for the contest.

2019-20 Design Build Fly Proposal

Executive Summary

This proposal outlines the University of New South Wales' (UNSW's) team's initial design, analysis, fabrication, testing and demonstration plan for the 2019-20 AIAA Design Build Fly (DBF) competition. This year, the competition focuses on the design of a banner towing bush plane. Specifically, the aircraft must be optimised to complete three fight mission profiles simulating passenger transport and banner operations. The team has prioritised a sensible design with an emphasis on drawing our decisions from well-founded literature. Our aim is to demonstrate excellent flight handling qualities, fabricated from practical and affordable materials and manufacturing methods while delivering creative mission system designs to maximise the team's overall score.

It was found from a sensitivity study that the number of passengers and the time taken to complete 3 laps for mission 2 had the greatest impact on the total score although all parameters had moderately similar affects to the final score. From this and previous difficulties with short take-off distances, the team proposes an aircraft that minimises empty weight in order to meet the 20ft take-off distance in missions 1 and 3 and maximum passenger capacity in mission 2. The team proposes a single-motor tractor propulsion system with a low-wing, conventional tail design. It has a proposed maximum take-off mass of 18lbs, requiring 33 lbf of thrust with a 5ft wingspan. The aerostructure is composed of a glass-fibre skin with internal reinforcing plywood ribs and carbon-fibre spars along the lengths of the wings for a high rigidity-to-weight ratio. The passengers and luggage will be magnetically attached to specialised compartments which alongside a two-stage banner deployment system will provide quick installation and operation. Manufacturing will take place on site at UNSW's MakerSpaces and is expected to begin as early as 10th December 2019 for testing manufacturing with composite materials. Wind-tunnel tests, ground and flight-testing methods will be employed to validate and verify the proposed design and predicted flight characteristics.

Management Summary

The UNSW DBF team is divided into the hierarchy illustrated in Figure 1. The Project Manager liaises between the academic and faculty advisors and the respective Technical Leads. In coordination with the project manager, a technical manager will oversee the details of the aircraft & systems design, manufacturing process and testing plan, and is responsible for the technical leads. The five technical leads include an aerodynamics lead, avionics & mission systems lead, aerostructures lead, flight performance & propulsion lead and a manufacturing lead. These leads were selected by the project manager based on their expertise and knowledge in their respective fields. Additionally, the technical leads have been designated into three teams; Airfoil & Control Surface Team, Fuselage & Landing Gear Team, and Avionics, Mission Systems & Propulsion Team. Each team will have general members to which relevant tasks can be delegated throughout the project.

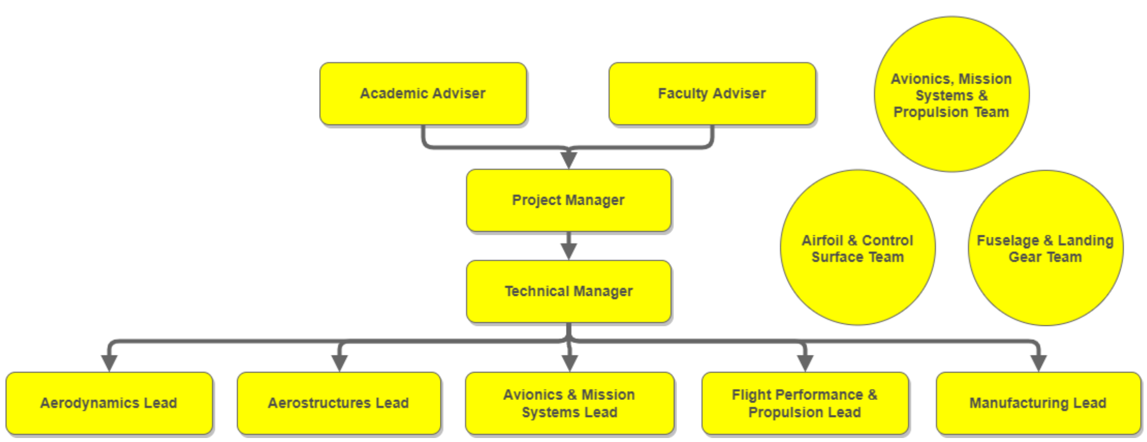

Figure 1. UNSW DBF Team Hierarchy

Table 1 below describes the skills required for leads to be effective within their role and to competently lead their teams. Whilst not mentioned individually below, all leads are required to have excellent communication skills, honesty, confidence, passion, accountability and creativity to ensure the strength of the team. The aerodynamics and manufacturing leads have been designated to the airfoil & control surface team, the aerostructures lead and technical manager have been designated to the fuselage & landing gear team, and the avionics & mission systems lead and propulsion lead have been designated to the avionics, mission systems & propulsion team.

Table 1. Role Skillset Breakdown

Role	Required Skill Set
Project Manager	Requires good communication skills, time management, project planning, budgeting, fundraising, organising and contingency planning
Technical Lead	Requires a good understanding of all aircraft requirements and can manage sub-leads to collaborate effectively in the design process
Aerodynamics Lead	Requires knowledge of CFD & X-foil software, and an understanding of principal aerodynamics concepts and theory
Avionics & Mission Systems Lead	Requires knowledge of all required electrical components and their safe usage, usage of CAD software, design brainstorming and concept fruition planning
Aerostructures Lead	Requires knowledge of FEA & CAD software, and an understanding of principal aerostructures concepts and theory
Flight Performance & Propulsion Lead	Requires knowledge of numerical computing software (MATLAB), an understanding of motor & propeller equations and practical calculations, and knowledge of avionics systems
Manufacturing Lead	Requires knowledge of safe work procedures, an understanding of composite manufacturing techniques, wide knowledge of materials, and an ability to plan manufacturing processes

Table 2 below details an estimated budget breakdown (in AUD) which includes both aircraft manufacturing and personnel (travel, accommodation and competition) costs. The personnel costs are calculated based on 8 people travelling to the competition and represent a large proportion of the total cost. The team is in the process of securing funding and is pursuing the UNSW Faculty of Engineering as a principal sponsor. Additional solicitation of material and financial sponsorship from both independent and AIAA industry partners is also underway. The proposed project schedule is illustrated in the GANTT chart in Figure 2.

Table 2. Estimated Budget

Department	Description	Proposed Amount
Avionics	Transmitter, receivers, servos, batteries, connectors	$ 940.00
Aerostructures	Glass fibre, carbon fibre, plywood, aluminium, plastics, glues, fasteners	$ 1,730.00
Manufacturing	Cutters, Sprays, Tapes, Vacuums, Film, Glue	$ 780.00
Propulsion	Motors, batteries, ESC, propellers	$ 860.00
Administration	Travel and accommodation to US fly-offs	$ 20,040.00
Miscellaneous	Practise aircraft, books, delivery expenses etc	$ 560.00
Total Aircraft		$ 4,870.00
Total Including Travel Expenses		$ 24,910.00

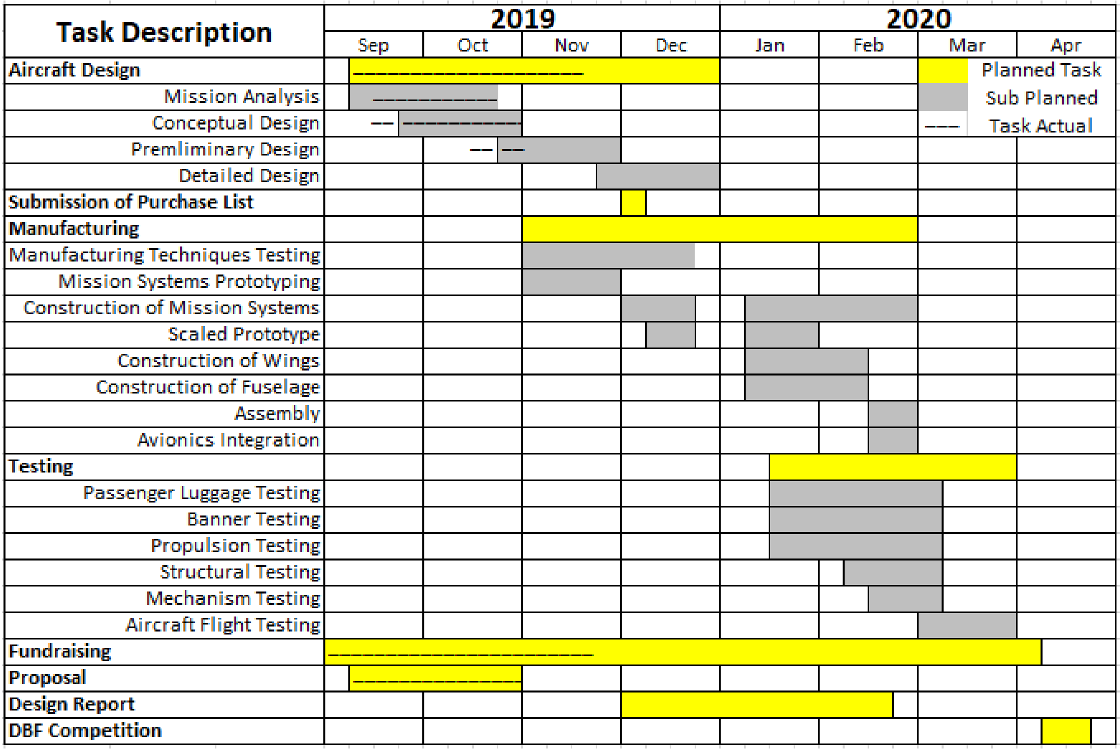

Figure 2. GANTT Chart

Conceptual Design Approach

The aim of the 2020 DBF competition is to design, build and fly an Unmanned Aerial Vehicle (UAV) that models a Banner-Towing Bush Plane capable of conducting charter flights. The aircraft will be judged based on three flight missions and one ground mission that are designed to subject it to different flight conditions and replicate missions that a Bush-Plane can carry. Table 3 outlines the sub-system requirements extracted from the mission rules.

Table 3 – Mission Requirements and Sub-System Requirements

Missions	**Requirements**	**Sub-System Requirements**
Ground Mission	• Demonstrate active flight controls remotely • Install banner and demonstrate banner deployment • Load passengers	• Research and test different banner deployment and passenger mounting mechanisms • Remote control of aircraft
Mission 1	Team must complete 3 laps within a 5-minute flight window with a successful landing.	• Minimising empty weight and stall speed to allow for short take-off of 20ft. • Designing a passenger-mounting mechanism that can secure passengers throughout flight. • Designing a banner-deployment system that can deploy and release mid-flight.
Mission 2	The aircraft loaded with passengers and luggage must complete 3 laps within a 5-minute flight window with successful landing.	
Mission 3	Aircraft must deploy a banner after the first upwind turn and release after crossing the finish line. It must complete as many laps as possible within a 10-minute flight window with a successful landing.	

From these extracted requirements, a sensitivity study was performed on the point allocations of the various missions weighing the weight of different plane design choices. Several parameters from each of the contributions for points were varied on a percentage basis from the initial design estimate to determine their percentile effect on the final score. The initial parameters were developed in Table 4. Figure 3 shows the results from this analysis.

Table 4. Reference Design Point for Sensitivity Analysis

Mission	Reference Design Point	Reference Score
Ground	50 Seconds Reference, 30 Seconds Minimum	0.60
2	10 Passengers, 70 Seconds Reference 14 Passengers Maximum, 80 Seconds Minimum	1.82
3	20 Laps, 11.81" Banner Reference 25 Laps, 19.69" Banner Maximum	2.48

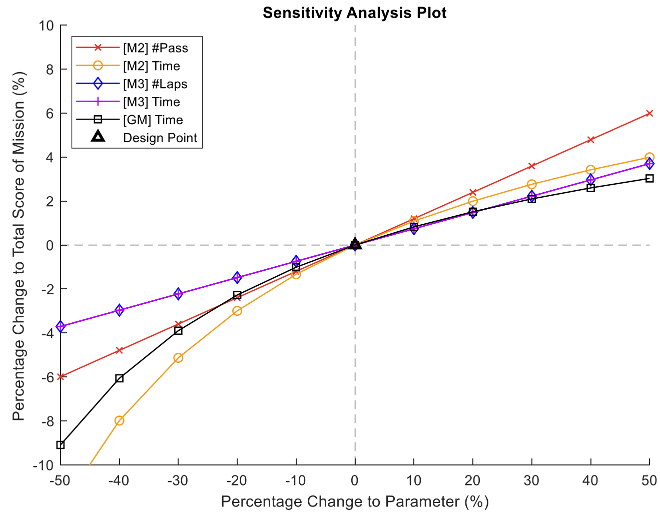

Figure 3. Sensitivity Analysis of Mission Parameters

From this analysis, it was found that the number of passengers and time required to complete 3 laps had a greater effect on the final score than all other mission parameters. Following this, it is evident that the flight time and number of passengers are the key factors that will result in the greatest amount of points. Hence the team put focus towards ensuring that the proposed aircraft will take-off at a distance no greater than 20 ft, carry at minimum 8 passengers and fly with a banner of length 11.81". As well, the team anticipates that the short take-off distance will be a challenge and will also put focus on high thrust generation and minimum drag.

The aircraft will have a maximum take-off weight of 18 lbs with approximately 3 lbs in passengers and luggage for Mission 2 and an estimated 14 lbs for Missions 1 and 3. In order to achieve short take-off, the aircraft requires around 33 lbs of thrust with a thrust to weight ratio of 1.875. To achieve sufficient lift, the wingspan was chosen at the maximum wingspan of 5 ft with a chord length of 1 ft and a total wing area of 5 ft^2, thereby attaining an aspect ratio of 5. A rectangular wing will be used with 2° angle of incidence and a 2D coefficient of lift of 0.96. The fuselage will consist of a teardrop shape connected to a cylindrical tail boom with a conventional tail with horizontal and vertical stabilisers. This will be validated by structural analysis of the aircraft under static and aerodynamic loads, alongside analysis of the stability of the aircraft in flight. A render of the proposed aircraft is included in Figure 4.

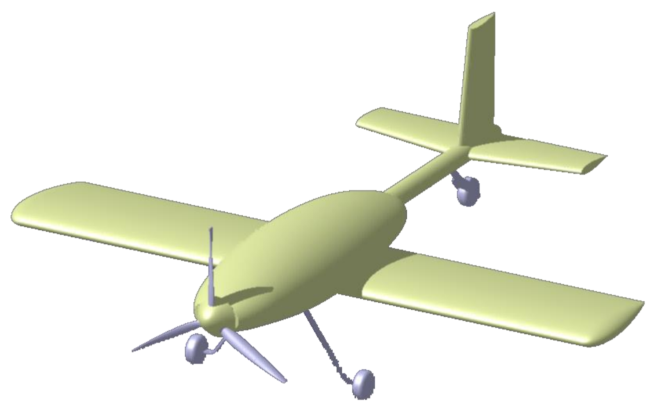

Figure 4 – Render of Proposed Aircraft Design

In order to deliver the mission requirements, the passenger mounting and banner deployment systems boast easy and secure installation of their sub-components to minimise time in the ground mission. Passengers will be magnetically attached to an underlying steel plate and aligned with angled slots. As well, the team proposes a two stage deployment system whereby the 2.36" x 11.81" banner is unfolded and deployed remotely and upon completion of the mission, the mount holding the banner is released through the detachment of a holding pin. These systems allow for rapid installation with sufficient strength and easy remote control for the banner.

Manufacturing Plan

The intended manufacturing plan provided in Figure 5 reflects the project timeline provided in Figure 2 and utilises two feedback streams. Manufacturing technique validation will be used to validate design manufacturability while airframe testing feedback allows for design and system iteration to optimise the final aircraft. A variation of composite manufacturing techniques, additive manufacturing and CNC machining will be trialled during November and December to determine their effectiveness in terms of cost, speed, reliability and weight.

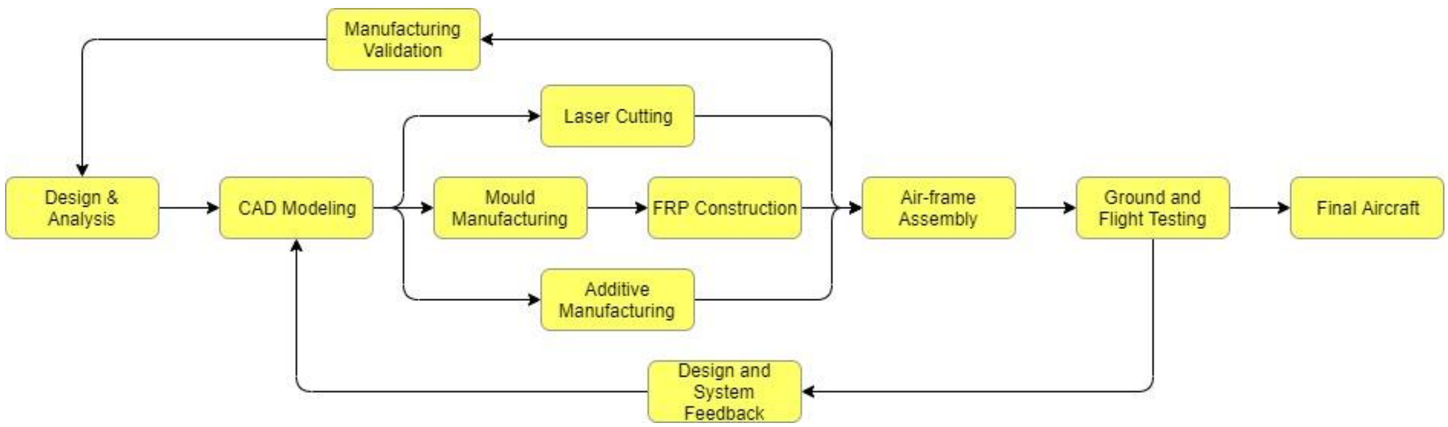

Figure 5. Manufacturing Plan

During the manufacture of the airframe, the primary emphasis is on producing a reliable airframe and improving surface finish to deliver a robust and low-drag airframe. This is achieved through the mix of technologies provided in Figure 5. The fuselage, wing and empennage will be constructed through FRP construction techniques utilising glass fibre and carried out positive or negative moulds and plugs depending on the required surface finish of the part. Secondary structure such as spars, ribs, floors, and mounting arrangements will be produced through a mix of plywood or prefabricated FRP panels cut to shape through laser cutting, CNC machining and additive manufacturing based on the required strength and applicability. Control surfaces and non-structural members are to be made through FRP and additive manufacturing to reduce complication due to part size and complexity.

Test Planning

There are four main aspects that make up our testing plan including the aircraft flight testing, structural testing, propulsion testing and mechanism testing. A scaled wind tunnel will be used to examine a prototype aircraft to determine its wing performance and flight characteristics in both loaded and unloaded conditions on 15/12/2019. Such a test will indicate whether the aircraft shape is suitable for the high gust conditions expected during April in Wichita. A structural test will be performed on 10/1/2020 to assess the glass fibre wings and the fuselage structure which will include both destructive and non-destructive components. A major concern is the wings snapping on a potential impact with the ground, therefore this test will determine how much additional structural support the wings will need, which will lead to added weight and reduced flight time. A thrust stand will be used to validate the performance of the motors, propellers and battery combination in order to maximize the aircraft's propulsive efficiency and will occur on 15/1/2020. Mechanism testing includes the passenger/luggage system testing and banner system testing and comprises of a fully connected system that will be evaluated on how reliable it is, how easy it is to use, and how quickly it can be set up. Passenger and luggage systems will also need to be evaluated on how they will perform as part of the fuselage. An additional test for the banner system will be needed that includes the final setup on the aircraft with inflight deployment and detachment on 20/1/2020. Flight day testing will be performed during March 2019 to confirm and tune stability, refine mission operations such as pre-flight checklists and mission strategies, confirm system integration and system reliability testing. This testing will indicate mission readiness and performance.

2019-20 Design Build Fly Proposal

Executive Summary

This proposal outlines the University of New South Wales' (UNSW's) team's initial design, analysis, fabrication, testing and demonstration plan for the 2019-20 AIAA Design Build Fly (DBF) competition. This year, the competition focuses on the design of a banner towing bush plane. Specifically, the aircraft must be optimised to complete three fight mission profiles simulating passenger transport and banner operations. The team has prioritised a sensible design with an emphasis on drawing our decisions from well-founded literature. Our aim is to demonstrate excellent flight handling qualities, fabricated from practical and affordable materials and manufacturing methods while delivering creative mission system designs to maximise the team's overall score.

It was found from a sensitivity study that the number of passengers and the time taken to complete 3 laps for mission 2 had the greatest impact on the total score although all parameters had moderately similar affects to the final score. From this and previous difficulties with short take-off distances, the team proposes an aircraft that minimises empty weight in order to meet the 20ft take-off distance in missions 1 and 3 and maximum passenger capacity in mission 2. The team proposes a single-motor tractor propulsion system with a low-wing, conventional tail design. It has a proposed maximum take-off mass of 18lbs, requiring 33 lbf of thrust with a 5ft wingspan. The aerostructure is composed of a glass-fibre skin with internal reinforcing plywood ribs and carbon-fibre spars along the lengths of the wings for a high rigidity-to-weight ratio. The passengers and luggage will be magnetically attached to specialised compartments which alongside a two-stage banner deployment system will provide quick installation and operation. Manufacturing will take place on site at UNSW's MakerSpaces and is expected to begin as early as 10th December 2019 for testing manufacturing with composite materials. Wind-tunnel tests, ground and flight-testing methods will be employed to validate and verify the proposed design and predicted flight characteristics.

Management Summary

The UNSW DBF team is divided into the hierarchy illustrated in Figure 1. The Project Manager liaises between the academic and faculty advisors and the respective Technical Leads. In coordination with the project manager, a technical manager will oversee the details of the aircraft & systems design, manufacturing process and testing plan, and is responsible for the technical leads. The five technical leads include an aerodynamics lead, avionics & mission systems lead, aerostructures lead, flight performance & propulsion lead and a manufacturing lead. These leads were selected by the project manager based on their expertise and knowledge in their respective fields. Additionally, the technical leads have been designated into three teams; Airfoil & Control Surface Team, Fuselage & Landing Gear Team, and Avionics, Mission Systems & Propulsion Team. Each team will have general members to which relevant tasks can be delegated throughout the project.

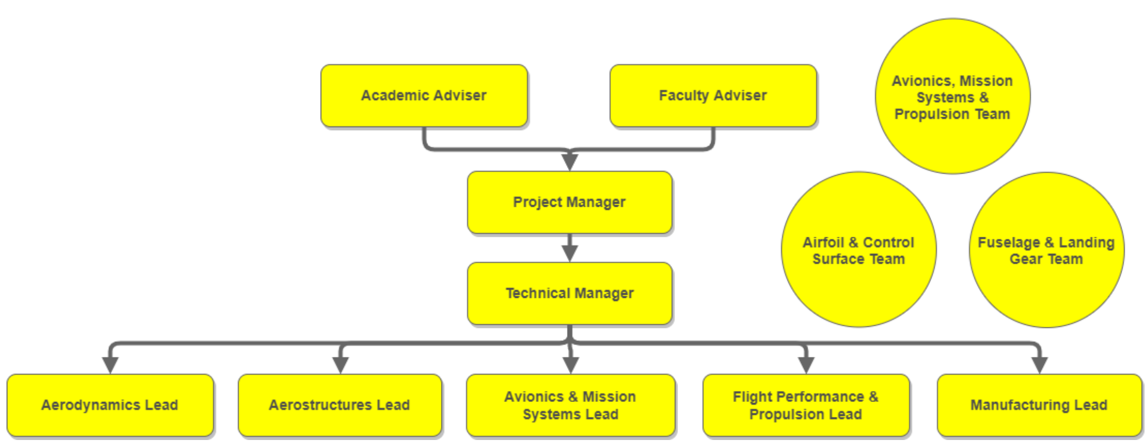

Figure 1. UNSW DBF Team Hierarchy

Table 1 below describes the skills required for leads to be effective within their role and to competently lead their teams. Whilst not mentioned individually below, all leads are required to have excellent communication skills, honesty, confidence, passion, accountability and creativity to ensure the strength of the team. The aerodynamics and manufacturing leads have been designated to the airfoil & control surface team, the aerostructures lead and technical manager have been designated to the fuselage & landing gear team, and the avionics & mission systems lead and propulsion lead have been designated to the avionics, mission systems & propulsion team.

Table 1. Role Skillset Breakdown

Role	**Required Skill Set**
Project Manager	Requires good communication skills, time management, project planning, budgeting, fundraising, organising and contingency planning
Technical Lead	Requires a good understanding of all aircraft requirements and can manage sub-leads to collaborate effectively in the design process
Aerodynamics Lead	Requires knowledge of CFD & X-foil software, and an understanding of principal aerodynamics concepts and theory
Avionics & Mission Systems Lead	Requires knowledge of all required electrical components and their safe usage, usage of CAD software, design brainstorming and concept fruition planning
Aerostructures Lead	Requires knowledge of FEA & CAD software, and an understanding of principal aerostructures concepts and theory
Flight Performance & Propulsion Lead	Requires knowledge of numerical computing software (MATLAB), an understanding of motor & propeller equations and practical calculations, and knowledge of avionics systems
Manufacturing Lead	Requires knowledge of safe work procedures, an understanding of composite manufacturing techniques, wide knowledge of materials, and an ability to plan manufacturing processes

Table 2 below details an estimated budget breakdown (in AUD) which includes both aircraft manufacturing and personnel (travel, accommodation and competition) costs. The personnel costs are calculated based on 8 people travelling to the competition and represent a large proportion of the total cost. The team is in the process of securing funding and is pursuing the UNSW Faculty of Engineering as a principal sponsor. Additional solicitation of material and financial sponsorship from both independent and AIAA industry partners is also underway. The proposed project schedule is illustrated in the GANTT chart in Figure 2.

Table 2. Estimated Budget

Department	**Description**	**Proposed Amount**
Avionics	Transmitter, receivers, servos, batteries, connectors	$ 940.00
Aerostructures	Glass fibre, carbon fibre, plywood, aluminium, plastics, glues, fasteners	$ 1,730.00
Manufacturing	Cutters, Sprays, Tapes, Vacuums, Film, Glue	$ 780.00
Propulsion	Motors, batteries, ESC, propellers	$ 860.00
Administration	Travel and accommodation to US fly-offs	$ 20,040.00
Miscellaneous	Practise aircraft, books, delivery expenses etc	$ 560.00
Total Aircraft		$ 4,870.00
Total Including Travel Expenses		$ 24,910.00

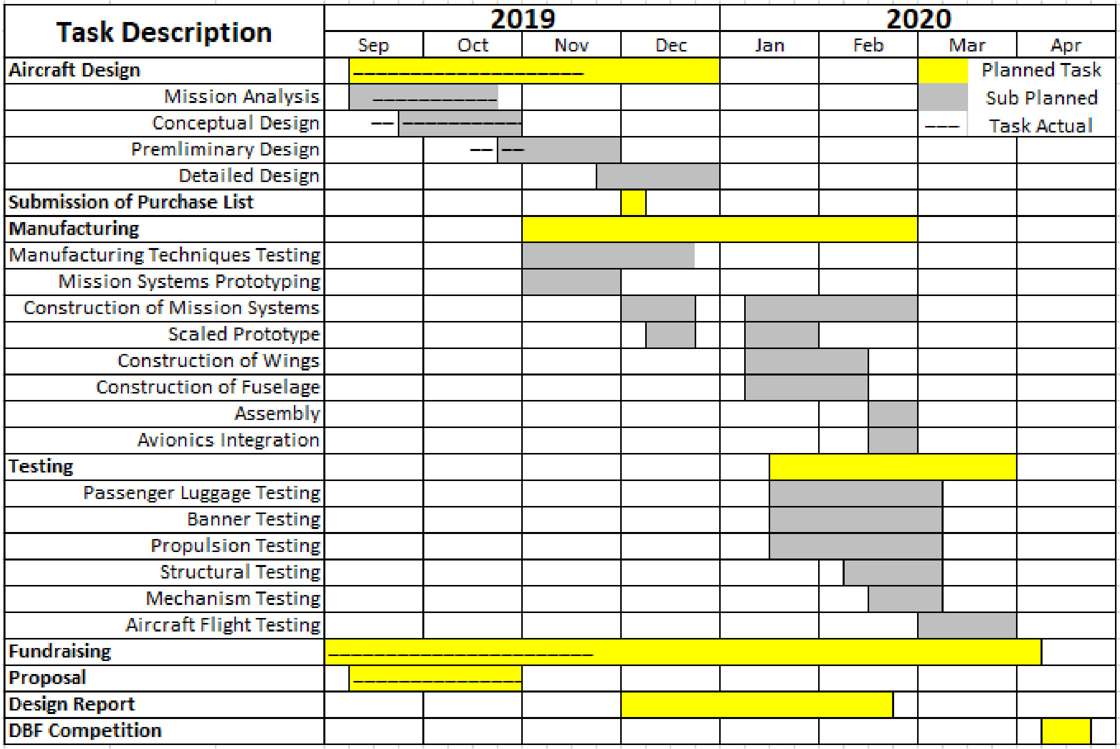

Figure 2. GANTT Chart

Conceptual Design Approach

The aim of the 2020 DBF competition is to design, build and fly an Unmanned Aerial Vehicle (UAV) that models a Banner-Towing Bush Plane capable of conducting charter flights. The aircraft will be judged based on three flight missions and one ground mission that are designed to subject it to different flight conditions and replicate missions that a Bush-Plane can carry. Table 3 outlines the sub-system requirements extracted from the mission rules.

Table 3 – Mission Requirements and Sub-System Requirements

Missions	**Requirements**	**Sub-System Requirements**
Ground Mission	• Demonstrate active flight controls remotely • Install banner and demonstrate banner deployment • Load passengers	• Research and test different banner deployment and passenger mounting mechanisms • Remote control of aircraft
Mission 1	Team must complete 3 laps within a 5-minute flight window with a successful landing.	• Minimising empty weight and stall speed to allow for short take-off of 20ft. • Designing a passenger-mounting mechanism that can secure passengers throughout flight. • Designing a banner-deployment system that can deploy and release mid-flight.
Mission 2	The aircraft loaded with passengers and luggage must complete 3 laps within a 5-minute flight window with successful landing.	
Mission 3	Aircraft must deploy a banner after the first upwind turn and release after crossing the finish line. It must complete as many laps as possible within a 10-minute flight window with a successful landing.	

From these extracted requirements, a sensitivity study was performed on the point allocations of the various missions weighing the weight of different plane design choices. Several parameters from each of the contributions for points were varied on a percentage basis from the initial design estimate to determine their percentile effect on the final score. The initial parameters were developed in Table 4. Figure 3 shows the results from this analysis.

Table 4. Reference Design Point for Sensitivity Analysis

Mission	Reference Design Point	Reference Score
Ground	50 Seconds Reference, 30 Seconds Minimum	0.60
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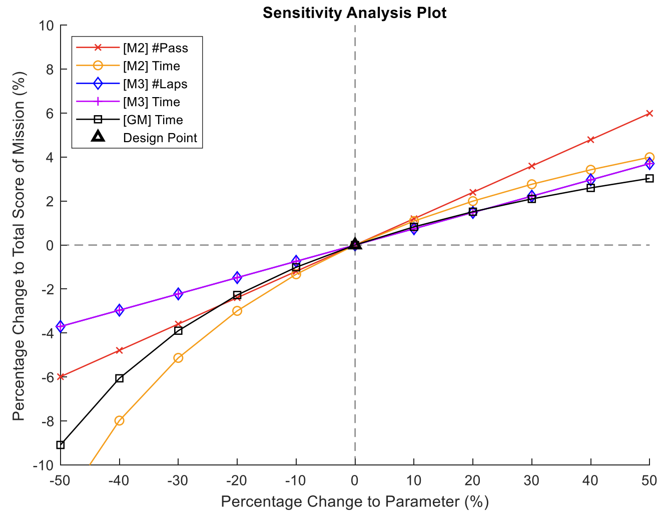

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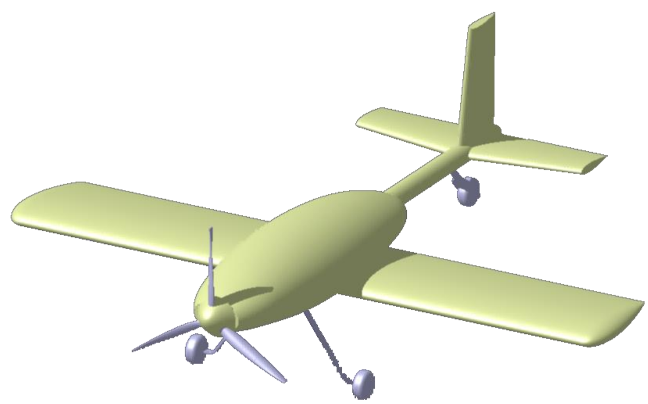

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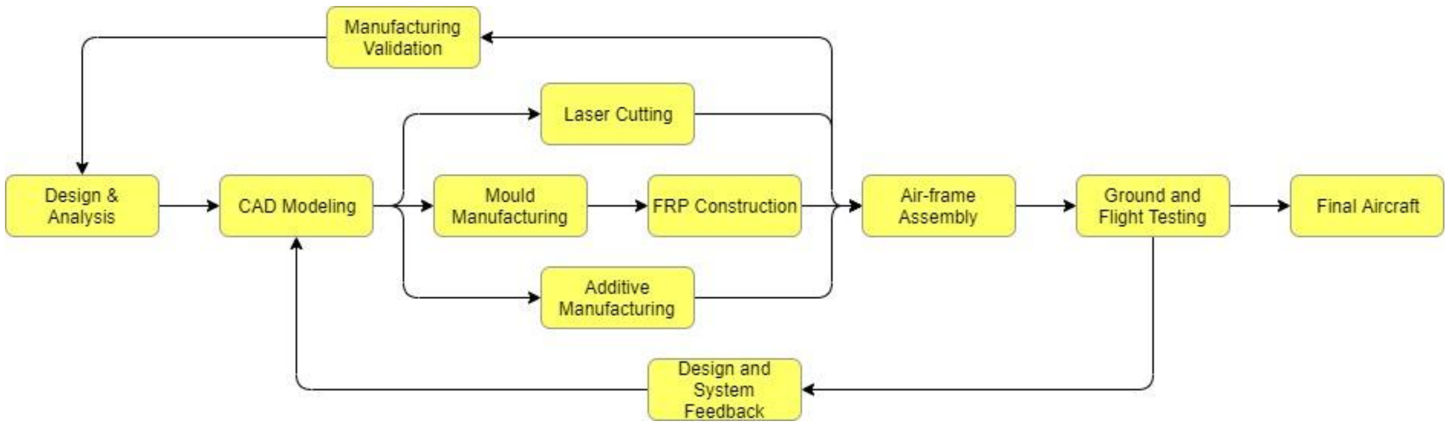

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