1. Executive Summary

The following proposal by Team Aerial Robotics Kharagpur (ARK), from the Indian Institute of Technology Kharagpur (IIT KGP) outlines the design, manufacturing and testing plan of "Pushpak" for the 2025-26 AIAA Design, Build, Fly (DBF) competition. The objective of this year's competition is to develop a Banner Towing Bush Plane to undertake charter missions, deploy and release a banner during the flight and maximise payload efficiency with a wingspan between 3 ft-5 ft.

A comprehensive Scoring Sensitivity Analysis was conducted to understand the contribution of different design variables towards the scoring system and mission requirements, revealing that cargo weight had a more significant effect on Mission 2 (M2) performance than the passenger count. The study also focused on the impacts of banner length and number of laps on minimising the Rated Airplane Cost (RAC). A Parametric analysis between battery capacity and scoring, identified a battery capacity of approximately 80 W-hr as the optimal choice. In addition, a scatter plot analysis between battery capacity and payload weight was also conducted in order to maximise efficiency and aerodynamic performance.

Based on trade studies for different configurations for the wings, propulsion system, banner deployment mechanism and the banner material, the team plans to build a high-wing, twin-puller configuration with a 5 ft wingspan. Polyester mesh was selected as the banner material along with a servo-actuated pin release mechanism. "Pushpak" aims to carry approximately 39-42 passenger rubber-ducks and 13-14 hockey pucks as cargo, with the aircraft frame being made of a composite of balsa wood and fiberglass.

The iterative design process will involve extensive CFD and FEA analysis, and once manufactured, the aircraft subcomponents will be put through rigorous subcomponent-level testing to ensure that they meet the requirements. The final assembly will undergo a set of ground tests as well as flight tests to simulate the actual mission performance.

2. Management Summary

2.1 Team Organisation

The Indian Institute of Technology Kharagpur AIAA DBF team constitutes 20 students, entirely composed of Juniors and Sophomores and organized into administrative and technical branches with oversight from Faculty Advisors which includes Prof. Sandeep Saha (Aerodynamics) and Prof. Mira Mitra (Aircraft Structures). Figure 1 shows the team structure. The team is led by the Project Manager who ensures the overall completion of the problem statement overseeing all operations. Administrative leads, led by the Communications Lead, handle non-technical requirements critical to competition readiness.

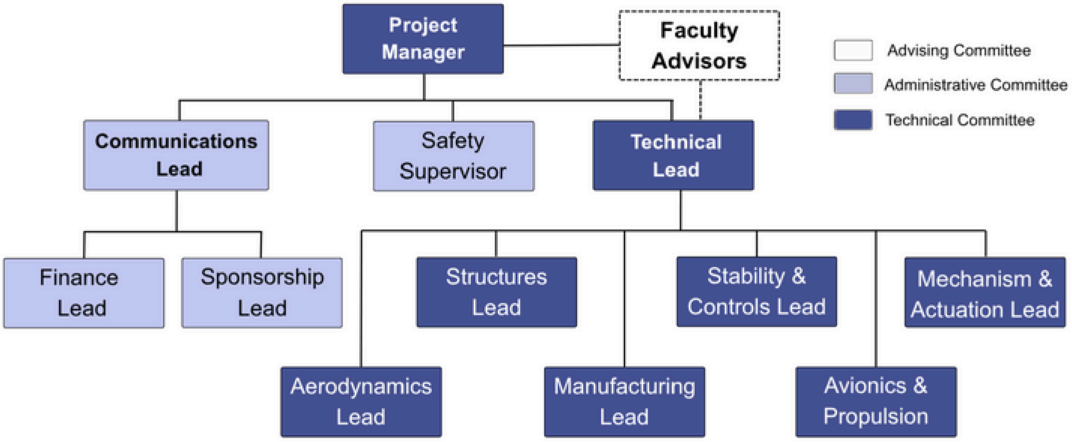


Figure 1: Organisational Structure

The Safety Supervisor is responsible for maintaining safe fabrication, assembly, and testing practices and also ensures that all design and operations follow AIAA 2026-DBF-Rules. The Finance Lead is responsible for budgeting, financial planning and keeping a track of funds at all times. The Sponsorship Lead is responsible for bringing financial deals and fundraising.

Sub-Teams	Responsibilty	Required Skill Set
Aerodynamics	Airfoil, wing & fuselage design, stability, Lift and Drag analysis	Aerodynamics Fundamentals, CAD, CFD, Wind Tunnel testing
Avionics & Propulsion	Selection of Motor, Battery, ESC & servos, Thrust analysis	Propulsion system knowledge of off-the-shelf products, Power analysis
Structures	Material selection, structural design to meet the structural stability requirements	CAD, FEA, Materials Theory
Mechanism & Actuation	Payload integration, Banner deployment & Release Mechanism	Assembly Processes, CAD, Actuation system knowledge
Stability & Controls	Control surface & Tail Sizing, Static and Dynamic stability	Stability & control theory, MATLAB, SIMULINK
Manufacturing	Composite fabrication, 3D printing & Final assembly	CNC & Tooling knowledge, Prototyping & rapid

Table 1: Subsystems Decomposition

The Technical Branch is led by the Technical Lead who is responsible for overall aircraft performance and subsystem integration. The technical lead also ensures that all the sub-teams work in cohesion, conducting weekly meetings with all the subsystem leads affirming all set deadlines are adhered. Table 1 shows the work distribution of the sub-teams. The Aerodynamics Team specializes in CFD using software programs like Ansys Fluent, XLFR5 & OpenVSP while the Structures Team is proficient in SolidWorks and Ansys Mechanical software programs.

2.2. Schedule

The proposed schedule for the design, manufacturing and testing of the Project aircraft is outlined in the Gantt Chart shown in Figure 2. The timeline is used to ensure that progress is on track to fulfil project milestones and deadlines to review progress and set goals for the coming week.

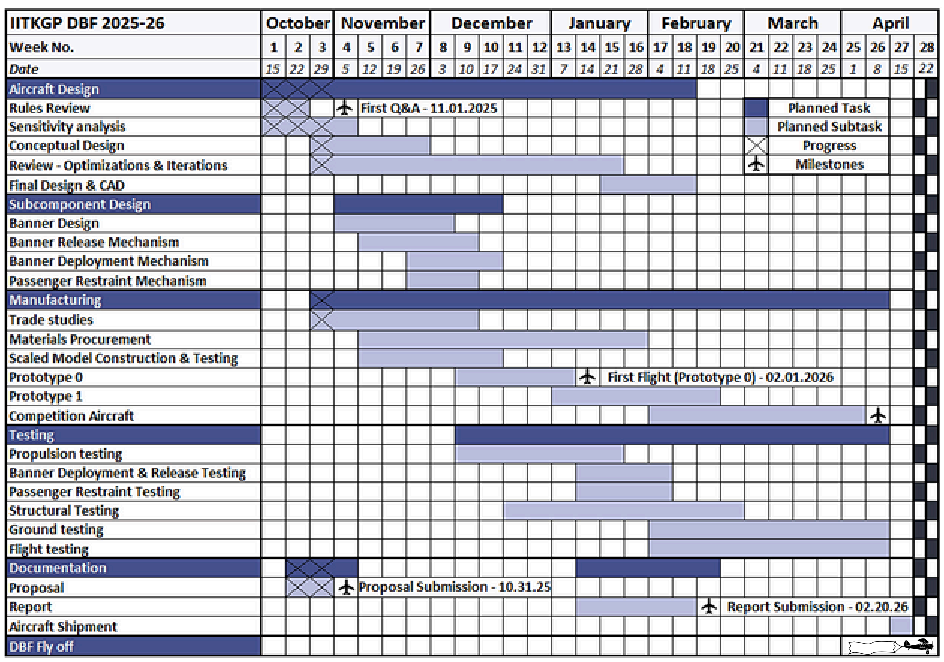


Figure 2: Timeline

Each sub-team holds meetings twice a week on Mondays and Thursdays, while meets with subject matter experts for review and feedback are held every two weeks, expediting the iterative process of design and implementation. Additional full team meetings are held as required to ensure timely completion of tasks to meet the deadlines.

2.3. Budget

The team's estimated budget is mentioned in Table 2. SRIC - IIT KGP will fund 67% of the total budget. The rest will be covered by external sponsors. Minimal manufacturing equipment will be bought because the Department of Aerospace Engineering will provide us access to their labs & resources including wind tunnels, CNC machines, 3D printers & composite manufacturing facilities. Since, ARK is a team from India, majority of the budget is alloted to the travel expense. Cost for manufacturing of 3 planes has been mentioned; one will be utilised for design iterations and the other two for the final iteration.

Category	Item	Estimated Budget
Travel	Airfare	$20,000
	Accomodation	$8,000
	Transportation	$1,000
	Shipping	$4,555
Avionics	Motors	$680
	Batteries	$410
	Propellers	$500
	Servos	$815
	Receiver	$170
	ESCs	$170
Structures	Balsa Wood	$850
	Aeroply	$230
	Oracover	$230
	Carbon fiber	$680
	Depron	$170
	Composites	$280
	Adhesives	$60
Manufacturing	Laser cutting	$340
	CNC	$170
Mission Systems	Payload	$178
	Banner	$100
Flight test	Miscellaneous	$170
Total Budget Estimate		$39,757

Table 2: Budget Estimate

3. Conceptual Design Approach

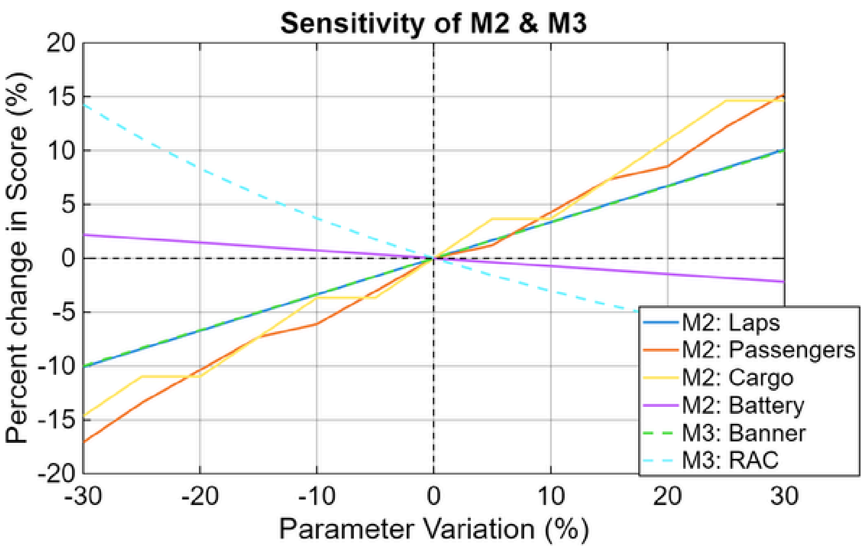
3.1 Mission Requirements

Mission	Scoring	Mission Requirements	Subsystem Requirements
M1: Test Flight	$M1 = 1.0$	• 3 laps, 5 minutes. • Land successfully.	• Sufficient thrust and battery capacity. • Stable aircraft for flight.
M2: Charter Flight	$M2 = 1 + \frac{NetIncome^{*}}{max_{all-teams}(NetIncome)}$	• Carry passengers and cargo. • Separate & secured cargo bays. • Land successfully.	• Adequate thrust & endurance. • Strong reinforced airframe. • Efficient battery system.
M3 : Banner Flight	$M3 = 2 + \frac{\frac{\#laps \times BannerLength}{RAC}}{max_{all-teams}(\frac{\#laps \times BannerLength}{RAC})}$	• Banner deployment, towing and release. • Land successfully.	• Robust banner deployment system. • Efficient battery system with high performance & endurance.
GM: Ground Mission	$GM = \frac{(T_{GM})_{MinAllTeams}}{(T_{GM})_{Team}}$	• Demonstrate active controls (in between all tasks as well). • Load, then unload passengers and cargo. • Install, deploy, and release the banner.	• Stable landing gear system. • Quick loading/unloading with sufficient space. • Smooth deploying mechanism for the banner.
Total Score = (Proposal score x 0.15 + 0.85 x Report Score) x (GM + M1 + M2 + M3) + Participation Score			

Table 3: Mission Decomposition

3.2 Scoring Sensitivity Analysis

The sensitivity analysis for DBF 2026 shows that laps, cargo, and banner length strongly influence total score, while battery capacity and Rated Airplane Cost (RAC) have negative effects. In M2, the plots for passengers and cargo show non-linear behavior due to constraints in the rulebook, which require a minimum passenger-to-cargo ratio of 3. An increase in cargo contributes significantly more to net income compared to passengers, making cargo optimization the key objective of M2. The battery capacity affects the score slightly by increasing operating cost through the efficiency factor, but the influence remains small.



Plot 1: M2 & M3 Sensitivity Analysis

For M3, banner length is primarily considered in the analysis, since both banner length and laps affect the score in the same way. Hence, maximizing banner length and minimizing RAC yield better results, enhancing overall score stability.

Mission 2: Design Optimization in Cruise

From the parametric variation analysis, it was observed only 2.5% decrease in score for 30% increase in battery. Hence, Battery with 80 W-hr capacity is chosen for 5-minute mission . Using steady flight conditions & power calculations, the following relation is derived:

$$\boxed{E_B = \frac{V}{10E}(11.02 + W_p)g}$$

Where E_B is energy, V is maximum average velocity, E is aerodynamic efficiency, W_p is payload weight, and g is acceleration due to gravity in standard units. Typical aerodynamic parameters for a small RC aircraft were used: zero lift drag coefficient as 0.035, induced drag factor (k) as 0.091 and planform area as 720 sq. in. At a 787.4 in/s cruise velocity, our feasible payload range is 5.5-9.0 lbs. To meet the 488.19-610.24 cubic inches cargo volume requirement, we are focusing our design and battery optimization on a target payload of 6.0 lb (nominally 5.9-6.1lb). Keeping in mind the constraint we have on using at least 3 ducks for each puck we would use, we should keep the 3:1 ratio of ducks to pucks to maximize our score. Considering that, the aircraft configuration includes 12 pucks and 36 ducks, totaling ~6.06 lb and ~603.07 cubic inches, positioning the design near optimal M2 performance region.

*where, NetIncome is given by: $NetIncome = \#p(6 + (2 - 0.5 \times EF)\#laps) + \#c(10 + (8 - 2 \times EF)\#laps) - \#laps \times 10 \times EF$

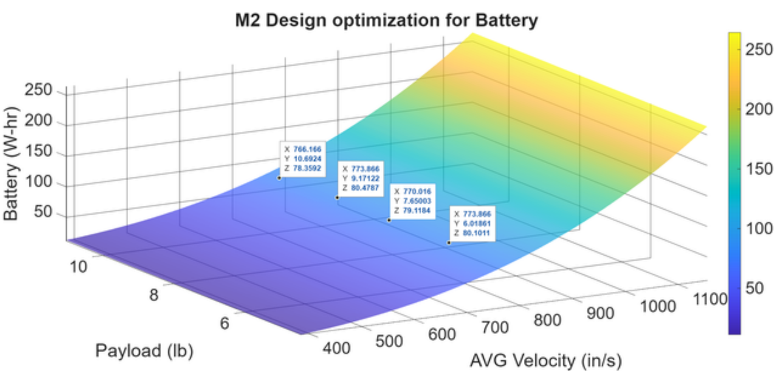
Mission 3: Design Optimization in Cruise:

For the cruise optimization, for a 5-minute flight, the maximum available power was assumed to be 900W, representing the propulsion limit during steady cruise. To include the drag contribution from the banner, its drag coefficient was estimated as $D = 0.05\frac{l}{h}$,where l and h denote the banner's length and height in standard units. The weight of the aircraft with the banner is approximated as 13.23 lbf.

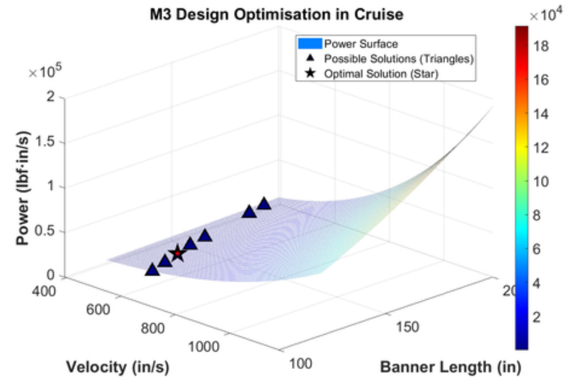
Using steady level flight condition & power balance relationship, the total power required during cruise was expressed as:

$$P_{\text{total}} = 1.11 * 10^{-6}\, l^2\, V^3 + 5.58 \times 10^{-4}\, V^3 + \frac{996.9}{V}$$

where W is the aircraft weight, V is the flight speed, and l is the banner length in standard units. Solving this relation for P total = 900 W yielded the optimal average velocity of 512.88 in/s and banner length of 137.76 in.



Plot 2: M2 - Design Optimization in Cruise



Plot 3: M3 - Design Optimization in Cruise

3.3. Trade Studies

A series of trade studies, consisting of tail and wing configurations, propulsion configuration, banner material, and banner deployment mechanism was done. A few important parameters were chosen for each component which were then rated in weighted categories, on a scale of 1-5 with 5 being the best. A convention tail was chosen for its reliable performance in previous competitions. A high-wing configuration was chosen as it offers higher stability and sufficient ground clearance. The propulsion system adopted a twin (double) puller configuration, offering maximum available thrust and better maneuverability.

Polyester mesh was selected as the banner material considering its favorable strength-to-weight ratio, and for the fact that perforations in the mesh would result in relatively lower drag than ripstop nylon. Finally, a servo-actuated, pin release mechanism was selected for banner deployment owing to its high reliability, low mass, and rapid reloading capability, in addition to easy manufacturing.

Parameters	Weightage	Conventional	T-Tail	H-Tail	V-Tail
Manufacturability	20%	5	4	3	3
Maneuverability	15%	4	4	5	5
Structural Strength	25%	5	4	5	3
Aerodynamics	15%	4	4	4	5
Stability	15%	5	5	5	3
Weight	10%	5	5	4	5
Total	**100%**	**4.7**	**4.25**	**4.35**	**3.8**

Table 4: Tail Configuration

3.4 Banner & Payload Mechanism:

The banner is attached to the fuselage with 2 rubber straps, deployed using 2 servo motors while it is released using a servo actuated U-buckle. Similarly, the payload is loaded and unloaded using a modular mechanism which can slide out of the fuselage for rapid loading. The passenger and cargo compartments are accessed through flaps on opposite directions.

Parameters	Weightage	Single Puller	Double Puller	Double Pusher
Manufacturability	20%	5	4	3
Weight	10%	5	4	4
Efficiency	20%	5	4	3
Ergonomics	10%	4	5	4
Stability	15%	4	5	5
Thrust	25%	3	5	5
Total	**100%**	**4.25**	**4.5**	**4**

Table 5: Propulsion

Parameters	Weightage	Pivoted Rod Mechanism	Servo Pin Release	Hatch Mechanism
Manufacturability	10%	3	5	4
Reliability	20%	3	5	5
Aerodynamic Impact	9%	1	3	5
Weight	20%	2	5	2
Stability Impact	10%	2	5	4
Loading Speed	15%	1	5	5
Deployment Speed	10%	2	5	3
Storage Ergonomics	6%	2	2	5
Total	**100%**	**2.06**	**4.64**	**4**

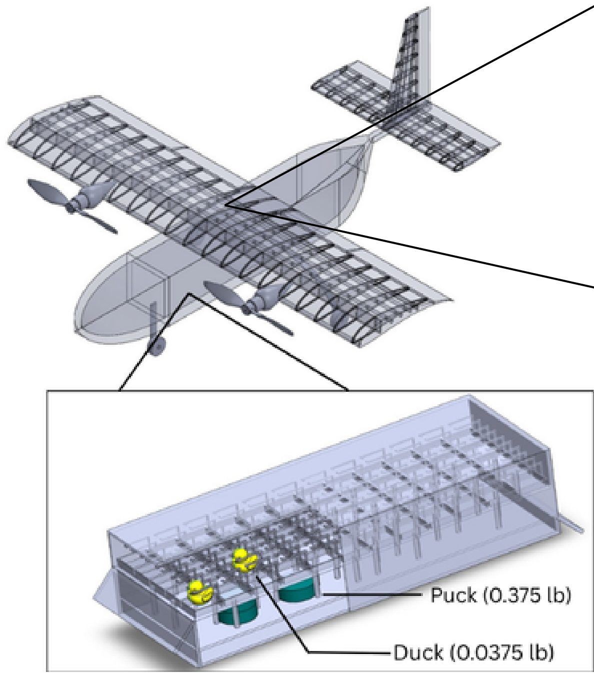
Table 6: Banner Deployment Mechanism

Parameters	Weightage	High-Wing	Mid-Wing	Low-Wing
Manufacturability	20%	5	1	3
Ergonomics	15%	5	2	4
Structural Strength	25%	3	3	5
Aerodynamic Stability	15%	5	4	3
Maneuverability	5%	2	4	5
Ground Clearance	20%	5	3	1
Total	**100%**	**4.35**	**2.65**	**3.35**

Table 7: Wing Configuration

Parameters	Weightage	Polyester	Nylon	Cotton	Vinyl
Weight	25%	3	5	3	1
Strength	30%	4	4	2	5
Low Drag	35%	5	3	4	3
Cost	10%	3	4	5	2
Total	**100%**	**4**	**3.9**	**3.25**	**3**

Table 8: Banner Material



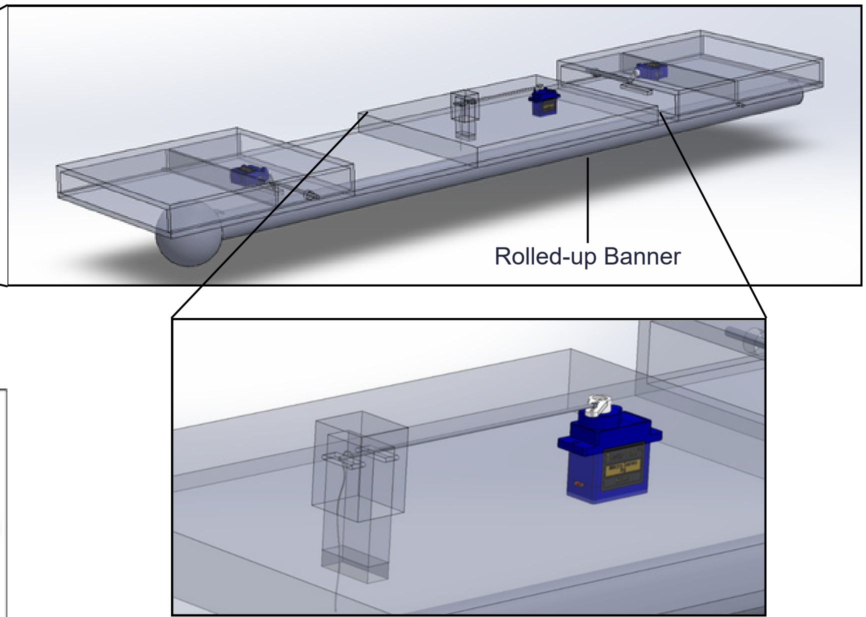


Figure 4: Banner Release and Deployment Mechanism

Figure 3: Payload Mechanism

3.5. Preliminary Design

Through the trade studies, the aircraft is a twin-prop, high-wing configuration was designed for cargo carrying and banner deployment, providing enhanced stability and necessary ground clearance as well as sufficient airspeed. The wingspan is 5 ft. For the target payload between 39-42 ducks and 13-14 pucks, a fixed cargo bay of 7″ × 7″ × 31.5″ is used. Ahead of this, an aerodynamic nose cone of roughly 12″ length houses the avionics, followed by a 5.9″ tapered section transitioning from the 7″ × 7″ cross-section to about 0.8″ × 0.8″. A tail boom of the same section extends ~10″, supporting the tailplanes. Propulsion is provided by 2 540KV BLDC motors driving contra-rotating 12″ propellers, generating 6-7 kg thrust. The tricycle landing gear maintains 4.7″ ground clearance and a wheelbase of approximately 20″, ensuring propeller and banner clearance during takeoff and taxiing.

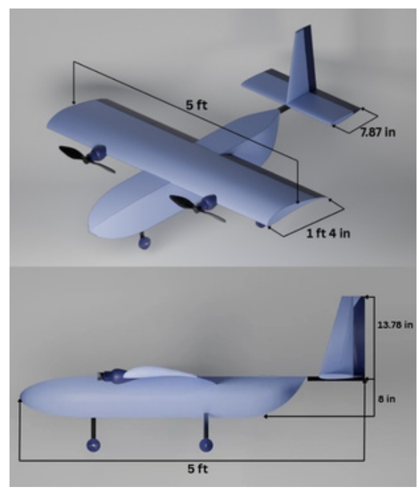


Figure 5: Conceptual CAD Model

Among the four airfoils: SD7062, Clark-Y, S1223, and NACA 2410, S1223 showed the highest aerodynamic efficiency but was less favorable for manufacturing and structural strength. Since M2 requires high payload capacity, structural strength was prioritized, making SD7062 the best choice. SD7062 also offered better aerodynamic efficiency and a higher stall angle than Clark-Y and NACA 2410. Overall, SD7062 provided the best balance of performance and strength.

4. Manufacturing Plan

The aircraft will first be modeled in CAD using SolidWorks, with aerodynamic analysis & CFD on Ansys Fluent and FEA using Ansys Mechanical. After the initial analysis, a rapid prototyped version will be built to study stability & control. On this, individual sub-system level tests for aerodynamics, propulsion, and structure will be conducted before the detailed CAD design is finalized. Once the design has been finalized, ribs and airfoils would be laser cut to precision, and composite manufacturing would be thoroughly studied for usage in fuselage to improve structural strength & reduce weight. We aim to use a fiberglass & Carbon fibre-epoxy layer along with foam and balsa core, and carbon-fiber rods for critical one-dimensional components.

Critical components and mechanisms such as the decks for the duck and puck, along with banner deployment and release will be 3D printed. The final airframe will be finished with Monokote wrap for protection and aerodynamic smoothness. Each part will be weighed and inspected to monitor build-up, aiming to build a modular design easy for transport, assembly and quick repair. The entire plan aims to ensure the aircraft is light, durable and mission-ready for competition.

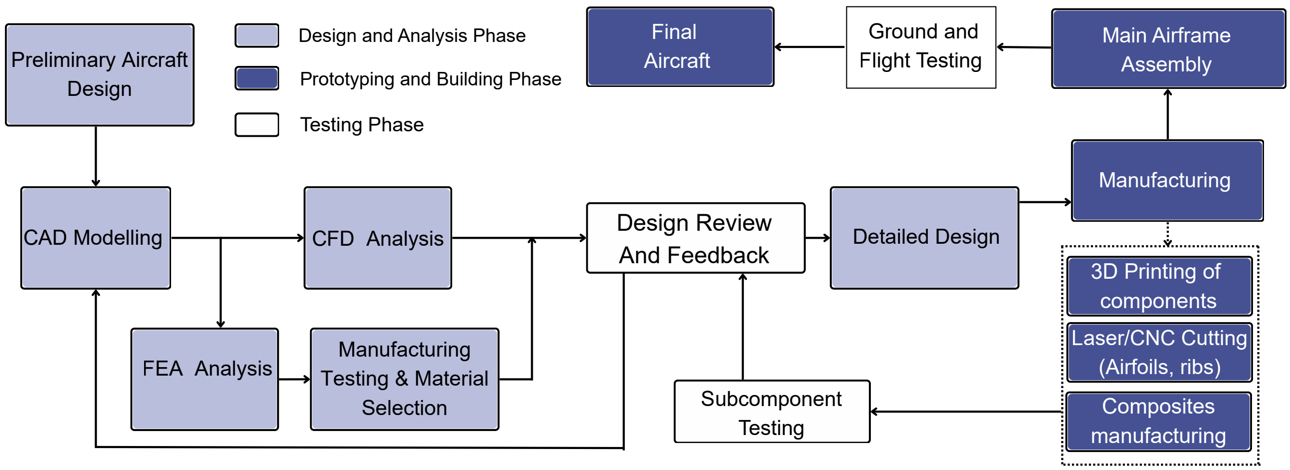


Figure 6: Manufacturing Plan

5. Testing Plan

The testing plan is outlined in Table 9. below. The Avionics & Propulsion team will carry out preliminary tests for static thrust, endurance, efficiencies, and overheating issues of the propulsion system, adhering to mission requirements. Ground verification tests ensure the proper functioning of all actuators and mechanisms under both ground and wind-tunnel-simulated flight conditions. These tests also confirm that the assembly time meets practical constraints and verify the operation of control surfaces under radio inputs. Structural tests will focus on wing structure scrutiny under operating load conditions while the Center of Gravity (CG) is located. Flight tests will be conducted on the mission plane under Standard Operating Procedures (SOP). The flight lap path would be similar to the actual path required in the mission and real-flight endurance in cruising, turning stability and dynamic payload response will be observed. Lastly, a full-systems test will be the confirmation for mission readiness and may highlight critical refinements, if any, before the competition.

Test Type	Sub- System	Test	Objective	Method
Preliminary Tests	Propulsion & Avionics	Static thrust test	Finding the most suitable battery, motor and propeller combination based on a suitable trade-off	Analysis using a static thrust stand
Ground Verification Tests	Mechanism & Actuation	Banner deployment and Release test	Ensuring that the banner is safely deployed and detatched	Verifying the deployment and detachment of the banner while on ground.
	Aerodynamics	Wind Tunnel Testing	Ensuring Banner deployment and wing and fuselage performance of initial prototype in flight conditions	Using Wind Tunnel to simulate flight conditions
	Mechanism & Actuation	Payload test	Ensuring safe passenger boarding and cargo loading	Loading and Unloading of payload on the aircraft
	Manufacturing	Assembly test	Optimizing the time necessary to assemble the aircraft along with payloads	Assembling the entire aircraft with payload while timed. Ensuring that desired time is achieved.
	Stability & Controls	Stability controls test	Verifying the control surface functioning	Power the receiver and ensure all control surfaces move in intended direction.
		Center of Gravity (CG) Location test	Verifying that the CG is at the intended position	Lift the aircraft using the fingertips along the theoretical CG spanwise axis and adjust until CG is located
	Structures	Wing Loading test	Verifying whether the wing can withstand payload	Lifting the aircraft by using a flat surface across the wings
Flight Tests	Stability & Controls	Cruise Test	Verifying the cruise speed without and increasing payload	Flying in cruise speed and measuring the rate of climb
		Turning Test	Verifying that the aircraft can turn without and increasing payload	Performing bank angle turn while ensuring stability along with rate of climb
	Mechanism & Actuation	Banner deployment and Release test	Verifying the banner deployment and release while in flight	Performing Mission 3 and ensuring successful and safe deployment and detachment of banner
	All Sub-sytems	Full Systems Test	Verifying that all sub-systems of the aircraft are functional in full operation	Attempting all Missions from 1 to 3 with Standard Operating Procedures

Table 9: Testing Plan Chart