1. Executive Summary

This proposal outlines the plan for the design, analysis, manufacturing, and testing of the "Peaking Jay" by the Johns Hopkins team for the 2025-2026 AIAA Design, Build, Fly (DBF) Competition. The objective is to complete three aerial missions and one ground mission focused on payload capacity, banner deployment, and release.

The aircraft is a 10.4-lb conventional single propeller puller plane design with a conventional empennage and tail dragger landing gear. The wing has a chord length of 10" and a wing span of 58". A cargo bay accessed from the nose holds 8 hockey pucks at the bottom of the fuselage; a passenger compartment holds 24 ducks above the cargo bay; and flight electronics lie at the nose of the plane. Under the cargo bay of the fuselage lies a 2 x 10-foot banner that will be deployed in-flight. In Mission 2 (M2), the team will load all payload to full capacity (4.8 lb), excluding the banner, for a net weight of 15.2 lb. The aircraft will cruise at 92 ft/s, completing 7 laps in the 5-minute window, resulting in a net income of 742. For Mission 3 (M3), the aircraft will cruise at 84 ft/s carrying only the banner, completing 5 laps in the 5-minute window, resulting in an unnormalized score of 286. This year's manufacturing methods include laser cutting, 3D printing, and several new methods for the team, including CNC routing, CNC hot wire cutting, and carbon fiber wet layup. The team will conduct testing of individual components, followed by ground and flight tests to validate the plane's structural integrity, control, and propulsion systems.

2. Management Summary

2.1 Team Organization

The student-led team is composed of 18 undergraduates, 11 of whom are underclassmen. The team is supported by a faculty advisor, two industry advisors, and three graduate advisors who participate in key design reviews. Figure 1 shows the organizational hierarchy. The president oversees operations and coordination across all subteams, with the treasurer and secretary acquiring sponsorships, managing finances, and communicating between sponsors and the team. On the technical side, the chief engineer leads system integration and directs four engineering subteams: structures, systems and aerodynamics, propulsion, and manufacturing. The pilot reports to the chief engineer and provides feedback based on aircraft handling and flight performance. Subteam responsibilities and required skills are summarized in Table 1.

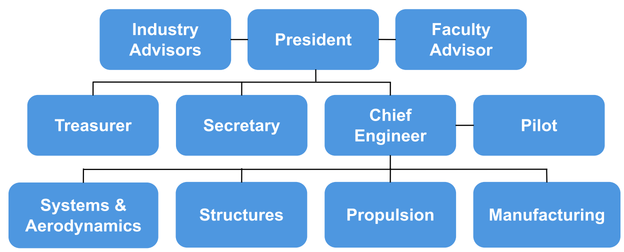
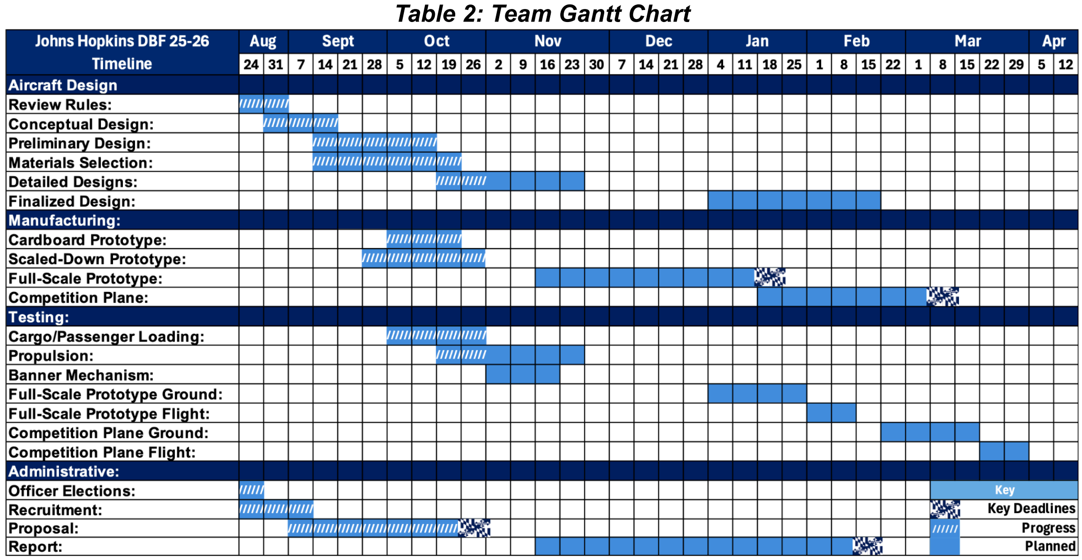


Figure 1: Team Organization

Table 1: Subteam Responsibilities

Subteam	Responsibilities	Knowledge In
Systems and Aerodynamics	Sizing of the plane including wing, control surfaces for desired performance. Selection of the aircraft configurations and airfoil	Proficiency in aerodynamics, aircraft stability, aircraft designing process
Propulsion	Selection of: battery, ESC, motor, propeller; propulsion testing; design thrust stand; thermal management	Proficiency in propulsion calculations, electronics as in ESC and microcomputers
Structure	Design aircraft structure: fuselage, landing gear, material selection, payload compartment, wing mount; stress evaluation; structural testing	Proficiency in CAD and structural analysis software (FEA), material sciences
Manufacturing	Manufacturing of all components of the plane and thrust stand	Proficiency in 3D printing, CNC machining, composite manufacturing

Table 2: Team Gantt Chart



2.2 Schedule

The team's schedule, outlined in Table 2, is reviewed throughout the process with key deadlines ensuring the plane is on target for completion. The chief engineer will hold subteam leads responsible for meeting the key deadlines for designing, manufacturing, and testing. The secretary will work with subteam leads to deliver the administrative key deadlines.

2.3 Budget

The team's projected budget is shown in Table 3. Current funding totals $8,900, sourced from the JHU Mechanical Engineering Department ($4,000), Reliable Robotics ($3,000), and fundraising efforts ($1,900). Additionally, industry sponsors cut expenses by about 18% through donations and discounts, including servo motors from Hitec USA, vacuum bags from Airtech, propellers from APC Propellers, a composite tube from DragonPlate, a battery from RoaringTop, a 40% discount on motors and ESCs from Scorpion Power System, and a 40% discount on carbon fiber weaves and resin from Venom Carbon. Travel is the largest share (61% of estimated costs, and 10 members are expected to travel), followed by structural materials (primarily composites). The team expects no manufacturing costs because JHU provides full access to fabrication facilities.

Table 3: Budget

Category	Description	Est. Cost	Team Expense
Travel	Flight & Luggage	$3,300	$3,300
	Lodging	$1,200	$1,200
	Shipping & Packaging	$500	$500
	Car Rental	$500	$500
	Fuel	$100	$100
	Food	$500	$500
Electronics	LiPo Batteries	$132	$66
	Motor	$640	$384
	ESC	$380	$228
	Servo motors	$700	$0
Structures	Composite Consumables	$300	$0
	Composite Fabric	$445	$267
	Composite Tubes	$690	$460
	Resin	$222	$134
	Propellers	$50	$0
	Landing Gear/Wheels	$120	$120
	XPS Foam Core	$125	$125
	Plywood	$125	$125
	Banner & Supplies	$150	$150
Competition	Fly-Off Registration Fee	$550	$550
Total Cost		**$10,729**	**$8,709**

3. Conceptual Design Approach

3.1 Analysis of Mission Requirements

The competition consists of three flight missions and a ground mission (GM) themed on a "Banner Towing Bush Plane". The analysis of the scoring and design requirements of the missions are displayed in Table 4.

Table 4: Mission Scoring and Requirements

	Description	Scoring	Sub-System Design Requirements
M1	No payload. Install batteries for takeoff within 5-minutes. Fly 3 laps within 5-minutes.	$M_1 = 1.0$	• Easily configurable to set up. • Reliable and able to achieve stable flight under varying conditions. • CG in the correct position with no payload.
M2	Install payload and batteries in 5 minutes. Payload of passengers and/or cargo within declared amount. Fly as many laps as possible within a 5-minute flight window.	$M_2 = 1 + \frac{(Net\ income)_{team}}{(Net\ income)_{max}}$ $Net\ income = Income - Cost$ $Income = N_p \times \left(6 + \left(2 \times N_{laps}\right)\right) + N_c \times (10 + \left(8 \times N_{laps}\right))$ $Cost = N_{laps} \times \frac{Total\ propulsion\ battery\ capacity}{100} \times (10 + \left(N_p \times 0.5\right) + (N_c \times 2)$	• The aircraft must withstand high wing loading. • The aircraft drag must be minimized. • Payload must be secured throughout the flight. • Minimum CG shift with added payload. • Maximize payload while balancing speed and cost. • The propulsion package must be efficient. • The motor must provide sufficient thrust to take off at a reasonable speed for the fully loaded configuration.
M3	Payload of the banner, deployed after the first upwind turn and released after crossing the finish line on the last lap. Fly as many laps as possible within a 5-minute flight window.	$M_3 = 2 + \frac{\left(\frac{N_{laps} \times L_{banner}}{0.05 * L_{wingspan} + 0.75}\right)_{team}}{\left(\frac{N_{laps} \times L_{banner}}{0.05 * L_{wingspan} + 0.75}\right)_{max}}$	• Minimum CG shift CG with and without banner. • Minimize drag induced from banner. • Remote release of banner during the flight. • The wingspan must be minimized while ensuring stable flight. • The banner must be upright and all surfaces are visible
GM	Timed loading and unloading of passengers and cargo, and installation, deployment and release of banner. Aircraft remains grounded.	$GM = \frac{(time)_{min}}{(time)_{team}}$	• Quickly load and unload passengers and cargo. • Quickly Install, deploy, and release the banner. • Ensure the above is possible without lifting the plane.
Competition Score		(0.15 x Proposal Score + 0.85 x Report Score) x (M1 + M2 + M3 + GM)+ Participation Score	

3.2 Trade Studies

A Pugh matrix in Table 5 was constructed to decide on wing, tail, landing gear, and propulsion configurations. Scoring was on a scale ranging from 1-10, with 10 being the most optimal design for the category. Each category was given relative weight based on importance in completing each of the three missions. A low-wing

Table 5: Pugh Matrices

Wing Configuration	Weight	Low	Middle	High
Stability	0.30	**4**	6	8
Manufacturability	0.25	**9**	7	8
Payload Access	0.45	**8**	3	5
Total Score	1	**7.05**	4.90	6.65

Landing Gear	Weight	Tail Dragger	Tricycle	4 Wheel
Stability	0.25	**7**	8	9
Manufacturability	0.40	**9**	6	5
Drag	0.35	**8**	6	4
Total Score	1	**8.15**	6.50	5.65

Propulsion Configuration	Weight	Tractor	Twin Tractors	Pusher
Power	0.15	**7**	9	6
Weight	0.15	**8**	5	6
Manufacturability	0.4	**9**	7	6
Efficiency	0.3	**7**	5	8
Total Score	1	**7.95**	6.40	6.60

Tail Configuration	Weight	Conventional	V Tail	T Tail
CG Effects	0.15	**7**	5	4
Manufacturability	0.30	**8**	4	5
Yaw Authority	0.35	**7**	5	9
Points of Failure	0.20	**8**	5	5
Total Score	1	**7.50**	4.70	6.25

design was chosen due to ease of payload access in M2 and quick loading during GM. Additionally, it provides improved ground effect, which assists with take-off under heavy payload conditions in M2. The tail dragger landing gear design was chosen for its ease of manufacturing and lower drag, which helps offset the drag generated by towing the banner in M3. The single-tractor configuration was chosen due to ease of integration and higher compatibility with the low-wing configuration, given the limited ground clearance. Lastly, the conventional tail was chosen due to simplicity and manufacturability, owing to prior experience.

3.3 Sensitivity Study of Design Parameters

The team conducted a design parameter sensitivity study to determine the parameters with the highest impact on scoring. This was done by changing design parameters by ±30% and then determining aircraft performance with a Python code that calculates simple lift and drag to predict the performance of the plane, hence the lap time. The results are shown in Figures 2 and 3.

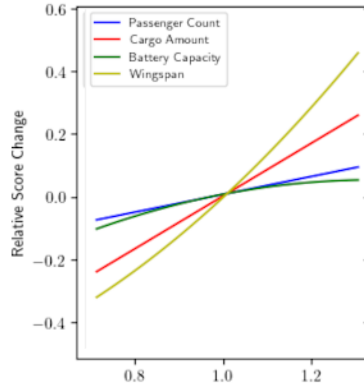


Figure 2: Mission 2 Sensitivity

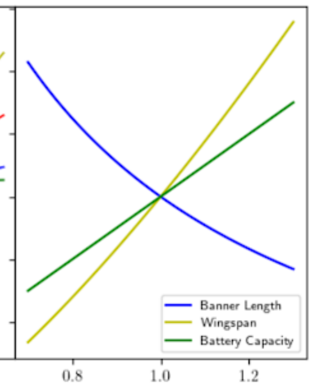


Figure 3: Mission 3 Sensitivity

For M2, the main performance specifications that affected the scoring were endurance and cargo contents. The team identified wingspan as the primary factor influencing the overall score despite the penalty for longer wingspan. Therefore, the team chose a large wingspan. Cargo was determined to be the second largest factor in determining the score, so the team designed a larger fuselage to hold more cargo while maintaining compliance with the minimum cargo-to-duck ratio of 1:3. For M3, the team found that increasing banner length reduced the score due to the additional drag affecting endurance. However, the team found that an increase in wingspan improved the plane's performance, especially at lower speeds, reducing the energy required to maintain flight. Thus, the team chose to balance wingspan and banner length to maximize scoring from the banner length without adversely affecting endurance. Figure 4 shows the breakdown of drag and thrust provided by the propeller, with the red point indicating the maximum cruise speed with the banner, and the blue point indicating it without the banner.

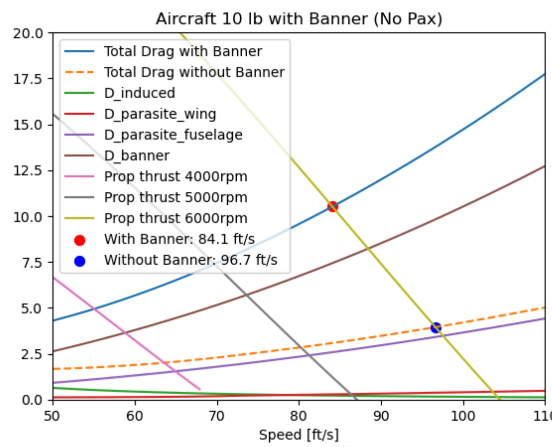


Figure 4: Thrust and drag at different airspeed

3.4 Preliminary Design

3.4.1 Peaking Jay

The Computer-Aided Design (CAD) model of the aircraft, shown in Figure 5, illustrates the overall design, detailing the views of the passenger compartment positioned above the cargo compartment and the banner stowed beneath the fuselage. The team created the preliminary design and sizing of the aircraft after the sub-system requirements, trade studies, and sensitivity analysis. For the wing, the NACA 4412 airfoil shape was chosen due to a high lift-to-drag (L/D) at 4° angle of attack. The wingspan is

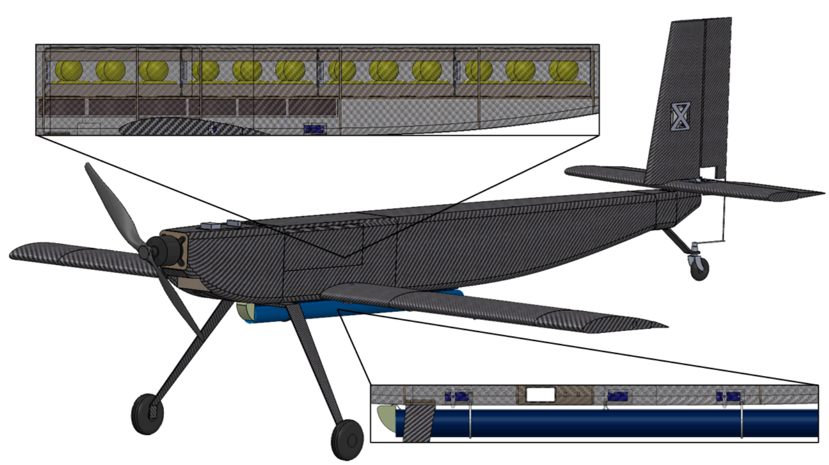


Figure 5: Aircraft CAD Model with Detailed Side Views of Payloads

sized to 58" to allow for manufacturing tolerances, and the chord length is sized to 10”. The team has chosen not to minimize the wingspan because, as discussed in the sensitivity studies, a larger wingspan allows a greater number of laps completed and reduces energy required for flight, which was critical for maximizing M2 and M3 scores. The wing will be mounted in the lower section of the fuselage to allow for easy payload access for M2 and GM. A rectangular 0.75" x 1.5" carbon fiber tube with a wall thickness of 0.0625" and 33 MSI fiber modulus, capable of withstanding up to 25 Gs of force with the full payload weight, runs through the middle 48" of the wing. The span of the horizontal stabilizer is sized to 20.94", and for the vertical stabilizer, it is 12.6", derived from the Tail Volume Coefficient recommended in Raymer (Aircraft Design: A Conceptual Approach, 2018) for sufficient moment generated. The NACA 0012 airfoil shape was selected for the stabilizers for its symmetry. The mean aerodynamic chord (MAC) of the horizontal stabilizer is 7.67", and 8.75” for the vertical stabilizer. For ease of transportation, the team designed the wing in two halves that can be attached to the carbon fiber spar, which is constrained to allow only translation within a plywood wing mount (Figure 6). To fully secure the wing, clevis pins running through the wing and the spar are used to secure the wing halves in place. The team designed a plywood mounting box to attach the vertical and horizontal stabilizers, and they will together be secured to a structure epoxied to the fuselage bulkheads via two carbon fiber rods, which function as locking pins. (Figure 7).

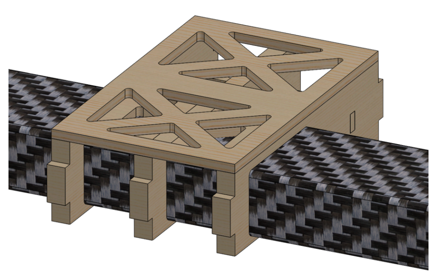


Figure 6: Wing Mount CAD Model

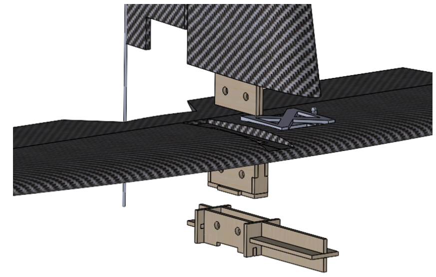


Figure 7: Tail Mount CAD Model

Fuselage dimensions were determined to minimize unused volume while containing passengers and cargo. It is 60” in length and 5" x 6” at the largest cross-section. The fuselage is compartmentalized into an avionics compartment, which houses all the electronics; passenger and cargo bays; and a compartment for the banner deploy and release mechanisms. Bulkheads are placed strategically throughout to provide structural reinforcement, ease alignment during assembly, and guide the loading of the passengers and cargo.

Following the outcome of the sensitivity analysis, the team decided to utilize a battery that maximizes the competition limit of 100 Wh capacity by selecting a 4500 mAh 6-cell LiPo Battery (capacity of 99.9 Wh). A Scorpion A-5025-415kv motor paired with a 100 A ESC was chosen to meet thrust and flight time requirements with a high efficiency of 91% according to eCalc. For M1 and M2, the team will install an APC 17x12E propeller for optimal motor load and maximum efficiency at cruise speeds. For M3, the team will install an APC 18x10E propeller to account for lower cruise speeds due to banner drag.

3.4.2 Passenger Compartment

Each passenger compartment unit is 4.13" x 8.75" x 3.2" and houses six ducks. The structure of the compartment will be made out of 1/16” bass wood, which will be laser-cut and super-glued together. Heavy-duty duct tape will be used to create a hinge between the back plate and the top plate. A 3D-printed ball-catch latch mechanism will be implemented to allow for quick locking and unlocking of the compartment. The entire passenger compartment consists of four units housing 24 ducks, with a total weight of 0.54 lb without ducks and 1.6 lb with ducks. “Egg crate” shaped memory foam will be implemented on the top and bottom of the compartment to ensure the ducks are secured throughout flight. After numerous tests with different combinations of ducks, the proposed dimensions of the unit, along with the foam cushioning, were confirmed to accommodate ducks of various shapes and sizes. The passenger compartment units will be linked by a string, allowing

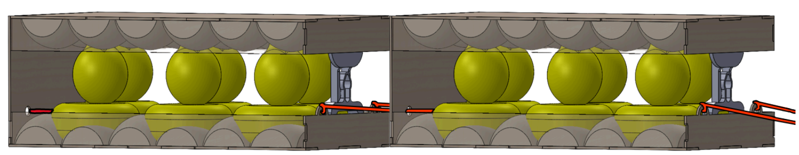


Figure 8: Passenger Compartment CAD Model

each compartment to slide through the side door on the fuselage sequentially while leaving enough space for the next compartment to be inserted or removed. Balsa wood guides are implemented on the bulkheads to assist with alignment during insertion and removal. This approach avoids the need for a large opening in the fuselage. Although linking the units, rather than having one single unit, slightly slows the loading process, it prevents compromising the fuselage structure. At the side door location, bulkheads and additional reinforcements will be included to prevent structural failure.

3.4.3 Cargo Bay

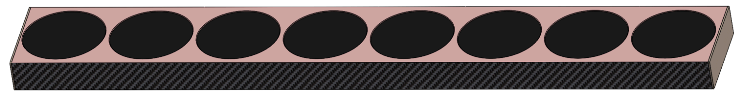


Figure 9: Cargo Bay CAD Model

The cargo bay is located under the passenger compartment and is separated by a floor. It will be constructed from hot wire-cut XPS foam reinforced with balsa panels at the front and back. A single layer of carbon fiber is wrapped around the foam to reduce bending during M2, GM, and loading operations. Balsa wood guides are implemented on the bulkheads to assist with alignment during insertion and removal. The cargo bay will be loaded through an opening in the nose section of the fuselage, a design choice that allows for fast access while requiring only a small opening, preserving fuselage structural integrity. Additionally, this loading approach is also compatible with the taildragger configuration of the aircraft.

3.4.4 Banner Deploy and Release Mechanism

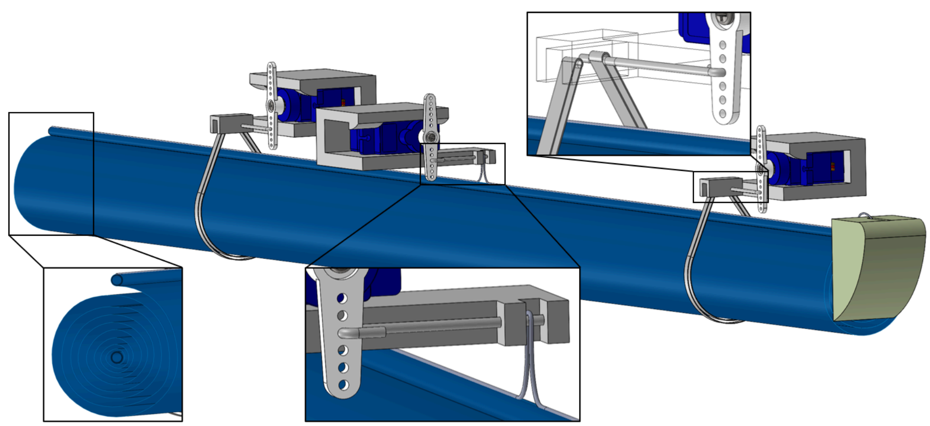


Figure 10: Banner Assembly CAD Model

The banner deployment and release mechanisms are shown in Figure 10. The banner is rolled up on a 0.125" outer diameter (OD) carbon fiber tube, referred to as the main tube. The opposite end of the banner is attached to a secondary tube of the same diameter. This secondary tube has strings tied to both ends. When stowed, the banner assembly is secured to the underside of the fuselage using a rubber band looped around a pin connected to the servo arm. During deployment, the servo pulls the pin, releasing the rubber band and allowing the banner to unroll to the upright configuration due to the frontal weight attached to one end of the main tube. The release mechanism functions similarly in that the servo retracts another pin, which releases the strings and detaches the banner assembly. The difference between the deploy and release mechanisms is that in the deploy mechanism, the rubber band remains attached to the aircraft upon deployment, as it loops around both the servo arm pin and a fixed rod structure. Lastly, the team has reviewed previous reports to determine the optimal material for the banner. Low-Density Polyethylene (LDPE), Kevlar, and Ripstop Nylon were identified as the top candidates, with LDPE being the preferred choice due to its low drag, low density, and high flexibility, allowing for easy storage.

3.5 Mission Targets

For Mission 1 (M1), the team will complete 3 laps in under two minutes, with a top flight speed of 97 ft/s. Adding 4.8 lb of payload for M2 (24 rubber ducks and 8 hockey pucks), the team will complete 7 laps in the five-minute time window with a top speed of 92 ft/s. During M3, the team will have a banner sized 2 feet by 10 feet while executing 5 laps in the five-minute time window, with a top speed of 84.1 ft/s.

4. Manufacturing Plan

The specific manufacturing processes are displayed in Figure 11. The team anticipates challenges in the loading of large-volume passengers and cargo in M2 due to tight spacing inside the fuselage. Therefore, a full-scale prototype made from cardboard will be used to evaluate payload dimensions and loading mechanisms. A second prototype will be made from carbon fiber with a shortened fuselage to evaluate manufacturing techniques and structural integrity.

The knowledge provided by the two prototypes will be used in the final aircraft, which consists of a three-layer carbon fiber fuselage shell made with wet layups on CNC-milled XPS foam molds, followed by precision machining to create openings for payload access and maintenance. Bulkheads and internal wooden structures will be laser cut, while the wing and tail will each consist of a single layer of carbon fiber over CNC hot wire-cut XPS foam. Non-structural components with complex shapes will be 3D printed using a low infill density to allow design flexibility and reduce weight.

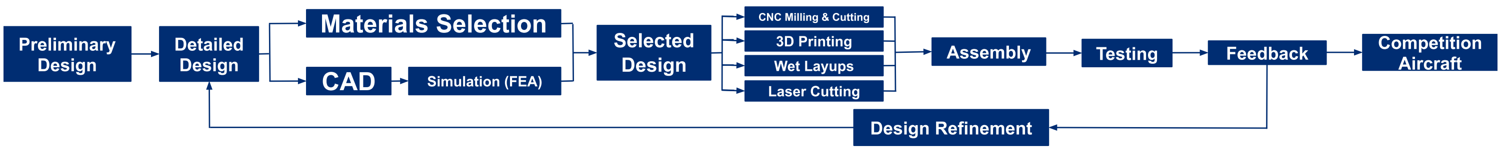


Figure 11: Manufacturing Design Flowchart

5. Testing Plan

Multiple tests will be conducted to validate design choices, assess structural integrity, and guide improvements for the final aircraft. Wing and fuselage structures will be tested to identify weak points for reinforcement, while propulsion tests will verify that sufficient thrust is generated for flight. Additional tests are outlined in Table 6.

Table 6: Testing plan

Category	Test	Verification/Research Objective	Method
Component Tests	Wing Loading Test	Wing withstands the full expected load with a safety factor of 1.5.	Sandbags are attached to the wing, and sand will be gradually loaded. Deflection of the wing is measured.
	Fuselage Landing Test	Fuselage withstands the load upon a hard landing.	Drop the aircraft with payload at a short height and examine the structural integrity.
	Thrust Test	Choose best combination of motor, propeller, and battery for propulsion.	Measure aspects of different propeller and motor combinations such as thrust, power, and RPM.
Ground Tests	Structure Tests	Wing and fuselage withstand payload weight.	Conduct three-point bending stress testing.
	CG Test	Location of the CG for each mission is valid.	Lift the aircraft by its wingtips and record CG.
	Full Throttle Test	Maximum endurance and efficiency of propulsive systems meet expectations.	Secure the plane to a stand and bring the thrust to full and verify the response and movement of control surfaces. Record performance.
	GM Test	Efficient and safe insertion of passengers, cargo, and banner capable.	Simulate GM environment. Time insertion of payloads and banner, make improvements accordingly.
	Banner Deployment Test	Servo motor actuation and safe separation of banner.	Verify the banner is secured, then test the deploy and release mechanisms.
	Electronics Test	Electronic systems turn on and perform intended functionalities.	Attach power connector to receiver. Verify electrical connections, including movement of control surfaces.
Flight Tests	First Flight	All aircraft systems are in full operation.	Fly the aircraft based on each mission's requirements. A microcontroller equipped with accelerometers, gyroscopes, altimeter, GPS, and airspeed sensor, will be installed to capture data logs. The data will be used to optimize the design variables and flying strategy. Pilot feedback will also serve as the basis for enhancing the design.
	Mission 1 Test	Aircraft completes M1.	
	Mission 2 Test	Aircraft's payload carrying abilities meet expectations.	
	Mission 3 Test	Banner stowing, deployment, and release function.	