1. EXECUTIVE SUMMARY

The Columbia University AIAA Chapter aims to design, build, and fly a fixed-wing radio-controlled aircraft to compete in the 2024-2025 AIAA Design/Build/Fly Competition. The objective is to create a maneuverable aircraft with detachable fuel tanks and a deployable X-1 test vehicle—a glider capable of controlled descent. After a careful review of the mission scoring criteria, a plan to maximize the final score was formed. The key parameters for success, in order, are the fuel tank and X-1 test vehicle attachment time, the propulsion system and lap time, and fuel tank mass.

The aircraft will be a single propeller, dihedral, high-wing design with a 6’ wingspan and a 14” chord S7055 airfoil. The aircraft will carry two 2 lb external fuel tanks and a 0.45 lb GPS-guided autonomous X-1 test vehicle, with the attachment mechanisms’ simplicity and speed prioritized. The aircraft will have a modular structure, with a central carbon fiber rod serving as the mounting point for various 3D-printed components. The propulsion system will feature a 16x6E propeller mounted to an Avian 5065-450 Kv, 1200 W motor powered by a 22.2 V, 99.9 Wh LiPo battery. A CAD model of the prototype will be created to test the preliminary design, conduct computational analysis through FEA and CFD, and manufacture the aircraft. Data from ground tests and flight tests over the months before Fly-Off will be used to perform iterative design revisions to create an optimal competition plane.

2. MANAGEMENT SUMMARY

2.1 Organizational Structure

Columbia AIAA is led by a student executive board with faculty and administrative advisors, as shown in Figure 1. The president communicates with the university administration and oversees general planning. The vice president assists the president with administrative tasks and handles team-wide communications. The treasurer handles club finances, material purchases, and sponsorships. The chief design engineer directs the plane design and CAD process, with the chief manufacturing engineer directing the manufacturing and testing processes. The chief safety engineer ensures club activities adhere to lab conduct and safety guidelines. The social chair manages social media and organizes team events to foster community. Under the chief engineers are the club’s four subteams: Aerodynamics, Propulsion/Electrical, Structures, and Payload. Each subteam is run by a subteam lead responsible for guiding newer members and delegating tasks. The responsibilities of each subteam are listed below in Table 1.

Subteam	Tasks	Skills
Aerodynamics	Wing and tail design and production, aerodynamic analysis	CFD (XFLR5), stability analysis and wing manufacturing
Propulsion / Electrical	Propulsion system selection, electronic systems testing	Propulsion calculations, circuit design and thrust tests
Structures	Fuselage design, landing gear selection, parts manufacturing	CAD, FEA, materials and manufacturing
Payload	Mechanism design and manufacturing	CAD, CFD, kinematics and materials

Table 1. Subteam responsibilities

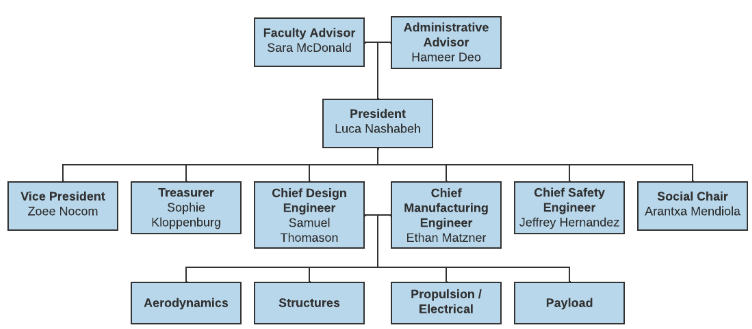

Figure 1. Team organizational structure

2.2 Comprehensive Project Schedule

The Gantt chart in Figure 2 illustrates the team's project schedule, which is used to ensure milestones are completed on time. The club holds weekly general body meetings and build sessions. The executive board also meets weekly to discuss objectives for upcoming meetings and the project schedule.

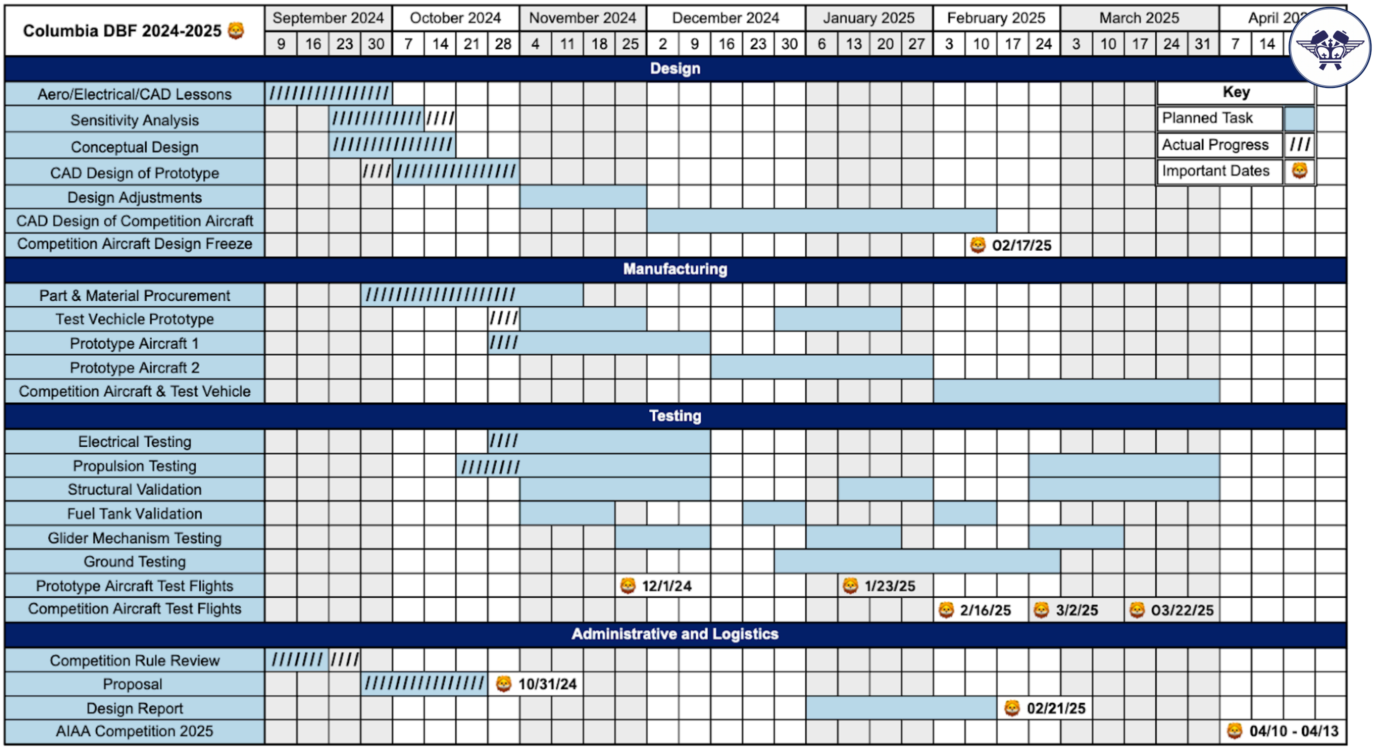

Figure 2. Schedule Gantt chart

2.3 Budget & Funding

The maximum estimated budget for fiscal year 2024-25 is given in Table 2. Estimates are based on the previous year's costs and current travel and material costs. Manufacturing equipment and many basic components have little to no associated costs, as they are either provided by Columbia University or can be reused from past years. The primary expense is travel costs (90%) to bring 12 students to the competition. Funding for the club is primarily sourced from Columbia University, with $8000 from the Mechanical Engineering department, and $6500 sourced from other internal sponsorships and funds. Additional sponsorships are anticipated to cover any further unexpected costs or additional spending.

3. CONCEPTUAL DESIGN APPROACH

3.1 Analysis of Mission Requirements

All flight missions have baseline points awarded for completion. Additional points in Mission 2 depend on speed and payload capacity. Additional points in Mission 3 depend on speed and the ability to accurately drop the X-1 test vehicle. Additional points in the Ground Mission (GM) depend on grounded configuration setup speed. More specific mission requirements for the X-1 supersonic flight program are listed below in Table 3. Additionally, after recognizing the individual problems that each section poses, design approaches for each mission were formed. Several variables were taken into consideration and initial baseline mission goals were decided. The results of these deliberations are given in Table 4.

Mission	Scoring	Requirements	Su
GM	$\min(t)/t$	Cycle the plane through flight mission configurations and prove flight readiness.	Qu fue en
M1: Delivery	1	Without the payload, complete 3 laps within a 5-minute flight window.	Ai su
M2: Captive Carry	$1 + \frac{W_{fuel}/t}{\max\left(W_{fuel}/t\right)}$	With payload (fuel and test vehicle), complete 3 laps for a competitive weight and time.	Ai inc

Categories	Allocated
Construction	**$510.00**
New Carbon Fiber	$300.00
PLA Filament	$40.00
Balsa Wood	$100.00
Foam Board	$20.00
MonoKote	$20.00
Landing Gear & Wheels	$30.00
Adhesives/Fasteners	**$35.00**
Foam Safe Superglue	$10.00
Hot Glue	$10.00
Velcro	$5.00
Nuts & Bolts	$10.00
Electronics	**$748.00**
Lithium Ion Batteries	$200.00
Servoless Payload Releases	$30.00
Brushless ESCs	$208.00
Glider Lighting System	$20.00
Wires	$10.00
Motor	$280.00
Competition (12 Students)	**$12,600.00**
Lodging	$4,000.00
Air Transportation	$4,320.00
Ground Transportation	$2,880.00
Food	$1,400.00
Social Events	**$100.00**
Total	**$13,993.00**

Table 2. 2024-25 Estimated Budget

M3: Launch	$2+\frac{N_{laps}+Bonus/W_{X-1}}{\max\left(N_{laps}+Bonus/W_{X-1}\right)}$	With fuel tanks empty, complete laps and release test vehicles.	The test vehicle must execute a 180° turn and fly a stable pattern to the bonus box.

Table 3. Mission scoring and requirements

Ground Mission	Implement a quick and secure way of attaching fuel tanks and the X-1 test vehicle. **Goal:** Achieve airworthy condition < 1 min.
Mission 1	Implement stable aircraft with dihedral, low center of mass, and high thrust-lift ratio. **Goal:** Complete 3 laps.
Mission 2	Implement a quick-release spring-loaded sliding mechanism to affix pylons to the airframe. Select a high-power, high-efficiency propulsion system. Use lightweight materials for the X-1 test vehicle. **Goals:** Fuel tank mass ≈ 4 lbs, test vehicle mass < 0.5 lbs, lap time < 50 s.
Mission 3	Implement a solenoid-powered mechanism to remotely deploy the X-1 test vehicle. Optimize the balance between battery size and motor power to ensure all laps are completed before the battery depletes. **Goals:** Deploy X-1 test vehicle and land in bonus area. Number of laps > 6.

Table 4. Design approach for each mission

3.2 Trade Studies

Representative trade studies are included in Table 5 below, with each criterion assigned a point value ranging from 1 (worst) to 3 (best). The point values are totaled, and the option with the highest scores was selected.

Wing Planform	Area/Footprint	Aerodynamics	Manufacturability	Score
Rectangular	**High (3)**	**Low (1)**	**Simple (3)**	**7**
Tapered	Moderate (2)	Moderate (2)	Moderate (2)	6
Elliptical	Low (1)	High (3)	Complex (1)	5
Tank Attachment	**Complexity**	**Consistency**	**Operating Speed**	**Score**
Sliding mechanism	**Low (3)**	**Moderate (2)**	**Fast (3)**	**8**
Rotating mechanism	High (1)	Low (1)	Moderate (2)	4
Shaft and bore	Moderate (2)	High (3)	Slow (1)	6
Aircraft Configuration	**Stability**	**Aerodynamics**	**Manufacturability**	**Score**
Conventional	**High (3)**	**Low (1)**	**Simple (3)**	**7**
Sport	Moderate (2)	Moderate (2)	Moderate (2)	6
Flying Wing	Low (1)	High (3)	Complex (1)	5

Table 5. Representative trade studies

3.3 Sensitivity Study of Design Parameters

A sensitivity analysis was performed using Python to determine the most critical and optimal parameters for the final design. Figure 3 shows how various mission parameters affect the raw additional score of both M2 and the GM. For M2, operating power and turn acceleration are the two most critical parameters as they impact the flight time. Although the payload weight is less critical, the parameter is still considered as it is easy to change. The GM, on the other hand, presents a significantly simpler optimization with a larger potential score increase. Thus, based on this sensitivity analysis, the GM

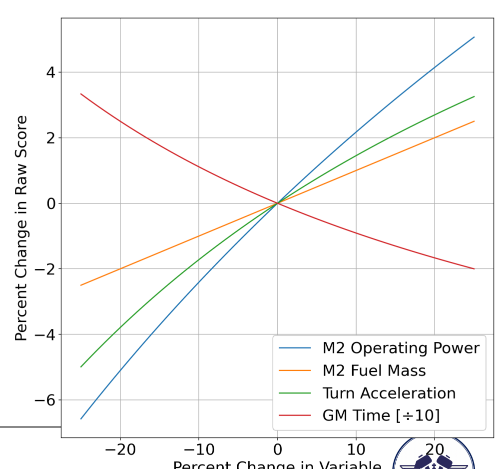

Figure 3. Sensitivity of raw mission scores. GM plot

optimization is prioritized—via the speed of the fuel tank and X-1 attachment systems—then the propulsion system, and lastly M2 fuel weight. To choose optimal parameters for the propulsion system, an optimization study for M3 was performed. Figure 4 shows that a 22.2 V, 4500 mAh battery (99.9 Wh), and 1150 W operating power provide the maximum number of M3 laps while remaining within competition rules. More fundamentally, and not captured by the above continuous analysis, is that completing a mission is required to score any points. Therefore stability, control authority, and consistency are emphasized in the final conceptual design.

3.4 Structural Conceptual Design

The design of the aircraft is centered around modularity and ease of repair. A 60” square carbon fiber rod will form the backbone of the aircraft to which most parts are mounted. Critical components like the motor mount, battery mount, wing crossbar, empennage mount, electronics compartment, payload pylons, and the X-1 hardpoint will be slid into place at various positions along the rod, and locked into place by a system of set screws. The parts will be designed to be rearrangeable along the rod, allowing for efficient rebalancing of the plane’s center of mass. 560 ml commercial beverage bottles will serve as external fuel tanks, and will slide into spring-locking dovetail mounts—inspired by Picatinny rails—that attach to the main structural rod. The wings will be constructed with shorter square carbon fiber rods, with each wing having separate rods to enable the dihedral design. To form the aerodynamic profile, a skeleton consisting of ribs placed along the rod will be wrapped in a lightweight skin. All propulsion system components, including the motor, battery, and electrical parts, will be secured using custom-designed mounts. The large landing gear provides a high angle of attack during takeoff, sufficient propeller clearance, and added suspension.

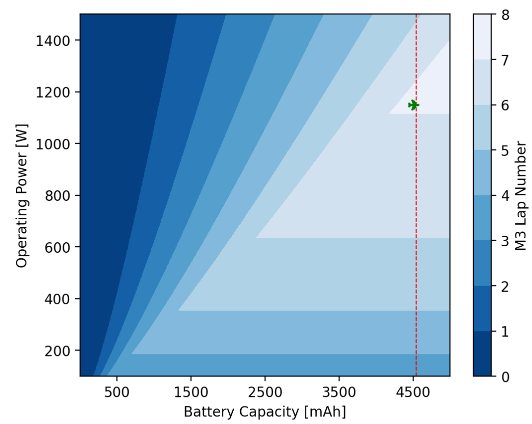

Figure 4. Propulsion system optimization for M3.
Red line indicates maximum propulsion system energy.

3.5 Aerodynamics Conceptual Design

Following the fundamental principle of stability and the tertiary goal of maximizing M2 weight, a flat-bottomed S7055 airfoil was selected, with a rectangular, tapered, slightly dihedral, high-wing configuration. The S7055 airfoil was chosen after analyzing many airfoils in airfoiltools.com, offering a high C_L (1.2) and C_L/C_D (80) in low Reynolds numbers flow regimes (200,000) with a ~5° range of safe angles of attack, maximizing stability first while not sacrificing lift. The S7055 also has a relatively simple design, allowing for easy manufacturing. The wingspan of the plane is 72” with a constant chord length of 14” to maximize wing area within the design and conventional aspect ratio constraints. A constant chord length also gives 0 Gaussian curvature, simplifying the Monokote wing construction. Rectangular control surfaces will be placed aft of the wing and actuated with servos. A high wing orientation with a 2° dihedral angle was chosen to maximize roll stability and streamline mounting. Preliminary weight balancing was performed to ensure the center of lift is ahead of the center of gravity to prevent a downward tendency. A conventional tail configuration was chosen to ensure consistency and control authority.

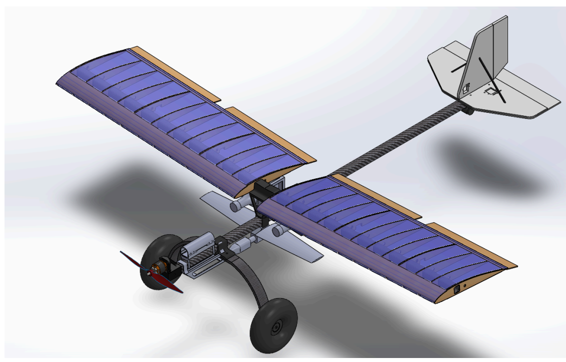
Figure 5. Conceptual aircraft CAD

3.6 Propulsion and Electrical Conceptual Design

A single propeller propulsion system was selected considering manufacturing simplicity and to minimize disruption to the aerodynamics and placement of fuel tanks. An Avian 5065-450 Kv, 1200 W DC brushless outrunner motor will be placed alongside a 100 A ESC near the nose of the aircraft. This motor, mounted with a 16x6E propeller, is optimized to carry the intended payload for M2 and M3. This motor will be powered by a 4500 mAh battery rated to 6S (22.2 V), which is below the continuous current limits of the motor within a safe margin.

3.7 X-1 Test Vehicle Conceptual Design

The X-1 test vehicle is designed with a top-mounted wing for increased stability and features a V-tail with servo-actuated control surfaces intended to provide control. The nose of the vehicle features a compartment to hold electronics including the GPS module and other circuitry. The glider is connected to the aircraft through a solenoid-actuated latch. The X-1's blinking LEDs will be attached via JST connectors and are powered by a 3S (11.1 V), 300 mAh Lipo battery through an astable multivibrator circuit, ensuring a robust, reliable, and simple design. The circuit will be triggered post-drop via Hall effect sensors on the glider.

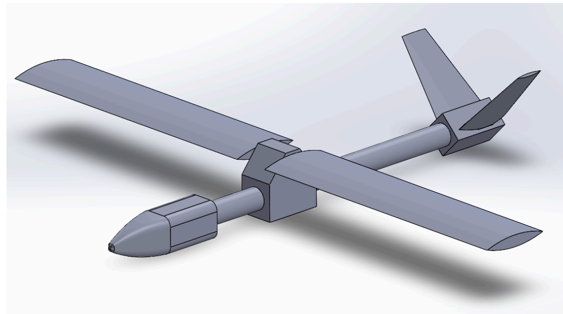

Figure 6. X-1 test vehicle conceptual design

4. MANUFACTURING PLAN

4.1 Manufacturing Flow

Revision and validation are central to the manufacturing flow. This allows us to ensure that each component performs well at an individual and a system level before final integration on the aircraft. This makes troubleshooting and root cause analysis significantly easier should problems arise during the eventual validation of the entire airframe. Most parts begin with a fit test prototype before creating fully formed models to verify dimensions and acceptable tolerances.

4.2 Critical Processes and Technologies

The components sliding onto the central carbon fiber rod will primarily be 3D printed with 15% infill. The wing's skeleton will be formed from a series of laser-cut balsa wood ribs that span the wing's square rod. A layer of Monokote will be heat-shrunk onto this skeleton structure, creating an exceptionally light wing. The empennage will be made using laser-cut foam board with thin carbon fiber spars to increase rigidity.
The landing gear will be a commercially available U-shaped carbon fiber layup. Commercially available foam and plastic wheels will be attached to the landing gear with a custom shaft turned on a lathe. All permanent hardware will be secured with a combination of Nylock nuts and Loctite Threadlocker, and all foam boards will be attached with foam-safe super glue.

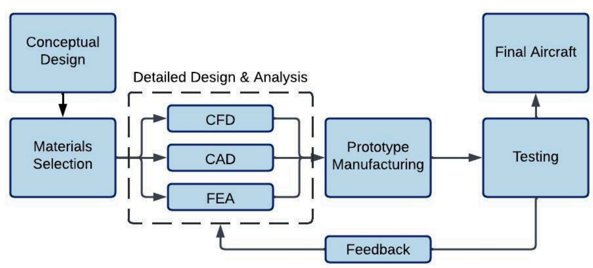

Figure 7. Manufacturing process flowchart

5. TEST PLANNING

Several tests will be performed on the aircraft and its components prior to competition to validate their design and performance as shown in Table 6. These tests will guide the design development of the final aircraft. Mock ground missions will be executed to test and improve the speed and efficiency of the payload attachment mechanisms and their ease of use. Flight testing will begin in a local model airfield in late November, and will simulate competition missions to validate flight objectives, characteristics, and procedures. Pilot feedback regarding the control of the plane will be documented and taken into account in future design iterations. Data will be quantitatively and qualitatively collected on the plane's endurance, speed, control, stability, and overall performance. The results from each test flight will be discussed as a team and used to adjust the aircraft's design as needed.

Test	Subteam	Method	Objective
Propulsion Tests			
Static Thrust	Electrical	Fix the system to a thrust bench, and run the motor until the batteries are fully discharged. Monitor metrics including thrust, current draw, and battery voltage.	Determine motor-generated thrust, battery current, power, and RPM of various propellor and motor combinations to determine the maximum flight time with a propeller test stand.
Ground Tests			
Wing Tip & g-Force	Aerodynamics	Mount the plane to the ground test fixture and install the payload. Simulate g-forces by installing additional weight beyond the payload.	Ensure the wings can carry the full weight of plane (including payload) without plastic deformation. Prove plane can withstand 10 g acceleration.
Propulsion System	Electrical	Validate motor, fuse, ESC, and battery circuit.	Determine preliminary circuit operation, discharge rate of batteries, and motor current draw.
Assembly	All	Simulate Ground Mission, a single student will assemble the test program airplane while timed.	Determine the time required to assemble the aircraft. Identify possible improvements.
Signal Range	Electrical	Incrementally move the controller away from aircraft and test the electrical components.	Find maximum operational distance for controller and aircraft.
Steering System	Electrical	Taxi the plane on the ground.	Test the maneuverability of the plane on ground.
Component Tests			
Landing Gear	Structures	Drop the weighted plane from 3 feet.	Test the impact resistance of the landing gear.
Component Security	Structures	Subject the fully loaded plane to higher g-forces than it will experience in flight and landing.	Ensure internal and external components are secured in place, e.g., batteries, payload, receiver, ESCs.
Wind Tunnel	Aerodynamics	Place a scale model of the wing into a wind tunnel.	Determine aerodynamic properties of the wing.
Gliding	Payload	Load the aircraft with equivalent weights and hand launch the aircraft.	Observe aircraft's stability and center of gravity with various parameters.
Structural	Structures	Apply expected loads while observing deformation and stress contractions in SOLIDWORKS.	Ensure structures can withstand expected loads during takeoff, flight, and landing.
Test Vehicle Release Mechanism	Payload & Electrical	Release the X-1 test vehicle with electrical components from the airplane onto padding.	Ensure the release mechanism performs as expected and the flashing lights of the X-1 test vehicle activate and remain operational.
Motor Mount	Structures	Attach weights equivalent to maximum thrust to the motor mounts.	Ensure the airframe can withstand the maximum thrust generated by motors.
Fuel Tank Pylon Mount	Payload	Attempt attaching and detaching filled fuel tank pylon mount while timed.	Determine attachment/detachment time and ergonomic efficency.
Flight Tests			
Test Vehicle Flight	Payload	Drop the X-1 test vehicle from a previously designed and tested airframe.	Evaluate mission efficacy for the X-1 test vehicle.
Flight Test #1	All	Perform the delivery flight with the aircraft.	Test basic flight capabilities, controllability, and stability of aircraft. Simulate Mission 1: Delivery Flight.
Flight Test #2	All	Fly the aircraft with the X-1 test vehicle and fuel tanks.	Simulate Mission 2: Captive Carry Flight. Ensure desired mission performance and identify possible improvements.
Flight Test #3	All	Fly the aircraft with fuel tanks and release the X-1 test vehicle.	Simulate Mission 3: Launch Flight. Ensure desired mission performance and identify possible improvements.

Table 6. Testing Plan