University of California, Irvine

2024-2025 AIAA Design/Build/Fly Proposal

I. Executive Summary

This proposal outlines the University of California, Irvine's team structure, design, manufacturing strategy, and test planning for the 2024-2025 AIAA Design/Build/Fly Competition. This year, the competition is focused on simulating an X-1 Supersonic Flight Test Program. The X-1 test vehicle is an autonomous glider that must demonstrate stable flight before safely landing within a predesignated area. The primary aircraft must be capable of carrying the glider and supporting at least two removable external fuel tanks outside of the glider's wingspan.

The team conducted several trade studies and sensitivity analyses to determine that the highest-scoring aircraft favors a high payload weight with moderate speeds. To achieve this, our aircraft features a tapered high wing, conventional tail, nose-mounted tractor motor, and tricycle landing gear with a fuselage to house the electronics. The glider is designed to be lightweight and equipped with a flight controller and GPS to facilitate autonomous navigation. Both vehicles are to be constructed primarily using a built-up balsa wood structure and carbon fiber rods to balance weight, manufacturability, and cost. The glider also utilizes a foam fuselage for additional strength to resist stresses during landing. Initial analysis predicts a maximum payload weight of 7 lbs, a maximum cruise speed of 75 ft/s, and a glider weight of 0.45 lbs for a total predicted mission score of 6.44. The following sections describe our timeline and approach for the design and fabrication of the aircraft.

II. Management Summary

2.1 Team Organization

Design/Build/Fly at UCI is a student-led design project consisting of undergraduate members, graduate advisors, and faculty advisors. The team organization chart is shown in Figure 1. The undergraduate team consists of 5 seniors and 19 non-seniors and is led by a Project Manager, Assistant Project Manager, and Chief Engineer. The Project and Assistant Project Manager organize meetings, manage the budget, and monitor overall progress in accordance with the schedule. The Chief Engineer oversees major design choices, the manufacturing process, and aircraft testing. Graduate and faculty advisors provide critical feedback and mentorship throughout the design process.

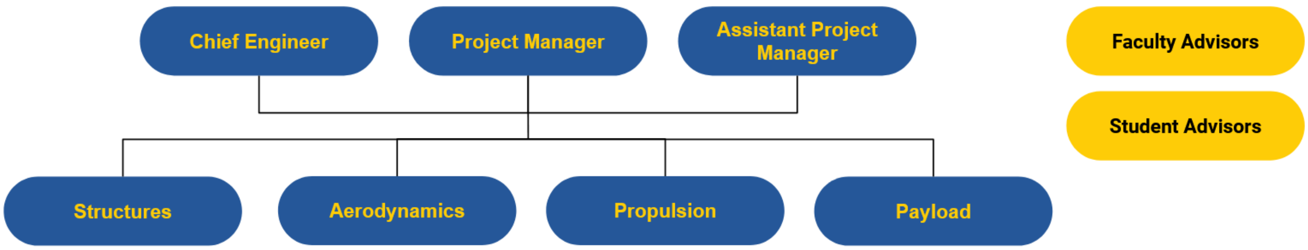

Figure 1. Team Organization Chart

The team is divided into four subteams: structures, aerodynamics, propulsion, and payload. The roles and required skills for each subteam are listed below in Table 1.

Subteam	Role	Skills
Structures	- Designs and manufactures the fuselage, landing gear, nose and tail cones, connections - Manufactures the wings and tails	- Knowledge of mechanics and materials - Manufacturing - CAD - Structural analysis (FEA)
Aerodynamics	- Performs scoring analysis and trade studies to optimize aircraft design - Sizes the wings and tails - Conducts CFDs to analyze aircraft performance	- Knowledge of aircraft performance - Aerodynamic Analysis (CFD) - Stability analysis (XFLR5) - Scoring analysis (MATLAB/Python)
Propulsion	- Selects electronic package for each mission - Performs testing of battery, motor(s), ESC, and propellers - Collect and tabulate thrust data using a test rig	- Knowledge of propulsion systems - Performance analysis software (ECalc/MotoCalc) - Wiring and electronics
Payload	- Designs components outside of the standard aircraft - Design of the autonomous glider - Conducts research into autonomous control systems	- Manufacturing - CAD - Simulation (FEA/CFD) - Programming flight controller

Table 1. Subteam and Role Description

2.2 Budget

The proposed budget breakdown is displayed in Table 2. The costs are based on previous years and divided into manufacturing costs, electronics costs, and estimated travel costs for 10 team members. In total, the team is expected to spend $12,540, primarily on travel expenses. Funding is acquired through lab fees, sponsorships, and student program funds.

2.3 Schedule

The proposed schedule for the 2024-2025 competition year is shown in Figure 2. The yellow and blue blocks indicate the expected timeline for each task, while the line represents actual progress. Important milestones are indicated by a marker, representing critical points in the design, development, and testing of the aircraft. Notably, the completion of each prototype is followed by a ground and flight test to determine areas of improvement.

Expense	Cost
Manufacturing	**$2,130.00**
Carbon Fiber Rod	$800.00
Balsa Wood	$1,000.00
Foam Board	$200.00
PLA Filament	$30.00
Laser-Cutting	$100.00
Electronics	**$2,410.00**
Battery	$300.00
ESC	$230.00
Receiver	$260.00
Motor	$640.00
Servo	$600.00
Propeller	$80.00
Flight Controller	$300.00
Travel	**$8,000.00**
Gas	$1,000.00
Lodging	$5,000.00
Food	$2,000.00
Total	**$12,540.00**

Table 2. Budget Breakdown

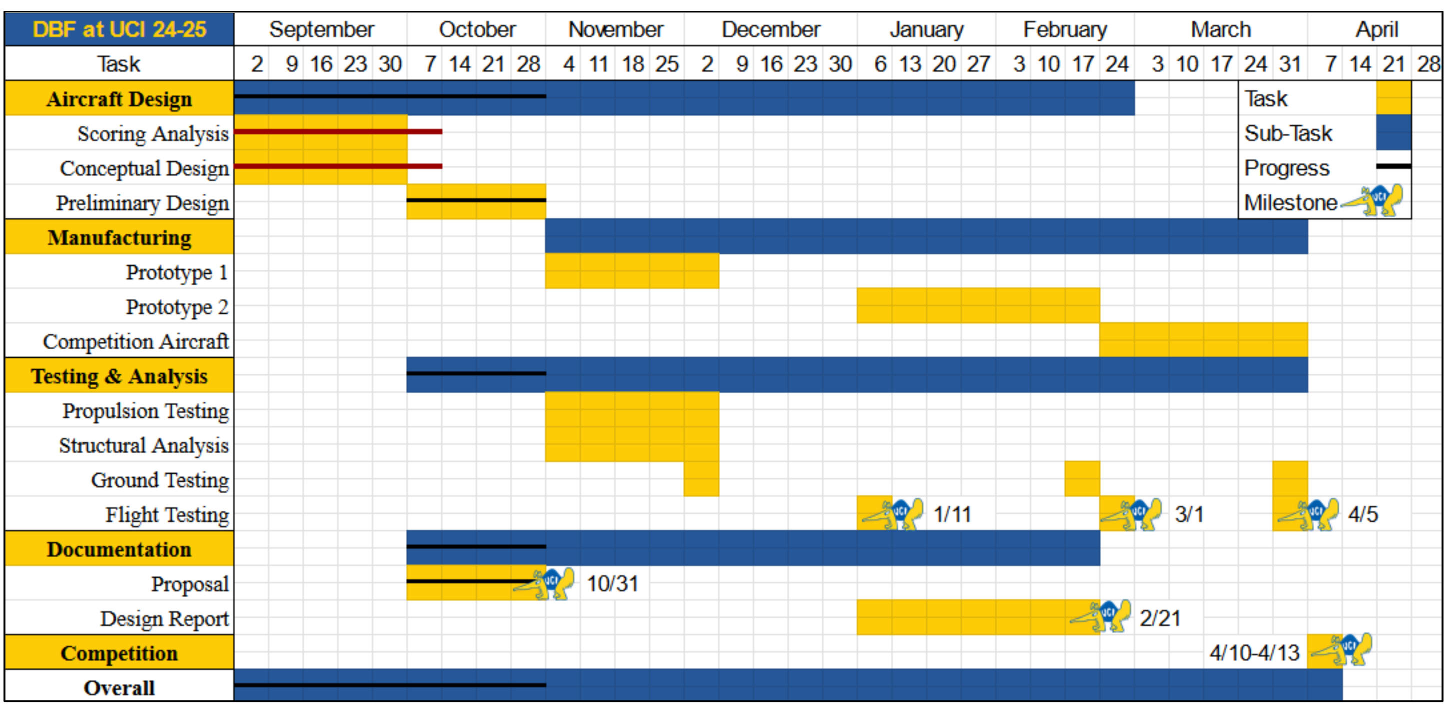

Figure 2. Gantt Chart with Major Milestones

III. Mission Outline

The 2024-2025 Design/Build/Fly Competition consists of 3 flight missions and 1 ground mission to simulate the X-1 Supersonic Flight Test Program. Table 3 below outlines each mission and requirements.

Mission	Description	Scoring	Team Requirements
Ground Mission	• Timed conversion of a fleet bomber aircraft to the test program airplane and a ground demonstration of a successful launch of the X-1 test vehicle. • Install all external pylons, declared fuel tanks, and the X-1 test vehicle and close and secure all access hatches. • Verify all flight controls are working properly and lights come on.	$GM = \frac{Time_{Min}}{Time_{Team}}$	• Create an aircraft with quick configuration mechanisms. • Ensure safe and easy installation of all required components.
Mission 1	• The ground crew member will put the airplane in the flight configuration and install the battery pack(s) within the 5-minute staging window. • Teams must complete 3 laps within a 5 minute flight window.	$M1 = 1.0$	• Design aircraft to successfully be able to complete 3 laps within the given timeframe.
Mission 2	• A minimum of two externally mounted fuel tanks must be carried. • Install the battery pack(s), X-1 test vehicle and fuel tanks within the 5-minute staging window. • Fly 3 laps within the 5-minute window.	$M2 = 1 + \frac{\left(\frac{Weight_{Fuel}}{Time}\right)_{Team}}{\left(\frac{Weight_{Fuel}}{Time}\right)_{Max}}$	• Design an aircraft that can support the weight of two external fuel tanks without substantially decreasing flight time.
Mission 3	• Install the battery pack(s), X-1 test vehicle and two external fuel tanks within the 5-minute staging window. • Complete laps within a 5-minute window and launch the X-1 test vehicle at 200-400 feet ASL after the first lap or any subsequent lap. • The airplane must complete the full lap after launching the X-1 test vehicle within the 5-minute window prior to landing. • The X-1 test vehicle must come to rest on the ground in a designated box with a blinking light within the 5-minute flight window for any bonus points to count.	$M3 = 2 + \frac{\left(\#\,Laps + \frac{Bonus\ Score}{X1\ Weight}\right)_{Team}}{\left(\#\,Laps + \frac{Bonus\ Score}{X1\ Weight}\right)_{Max}}$	• Optimize the number of laps able to be completed while successfully landing the X-1 test vehicle within the time frame and designated box. • Create a test vehicle that can make a successful autonomous landing once launched.
Report	• Document team structure and information flow. • Show full engineering design process. • Explain information gained and lessons learned throughout the year.	$Score\ out\ of\ 100\ points$	• Document progress throughout the year. • Meet with mentors to discuss reports and airplane performance.
Overall Score	(Design Report Score*.85 + Proposal Score*.15) + (GM + M1 + M2 + M3) + Participation Score		

Table 3. Mission Breakdown with Scoring and Requirements

3.2 Sensitivity Analysis

After breaking down each mission into the various scoring components, a sensitivity analysis was performed in order to analyze the importance of each scoring variable. Figure 3 shows how each variable impacts the percent change in total mission scores. Increasing fuel weight causes the highest percent increase in mission score. In addition, aircraft speed factors heavily into the scoring since a higher speed will both decrease the time to complete 3 laps for M2 and increase the number of total laps for M3. GM has an inverse relationship with M2 Fuel Weight. Additional trade studies were conducted to determine the ideal balance between fuel weight and aircraft speed.

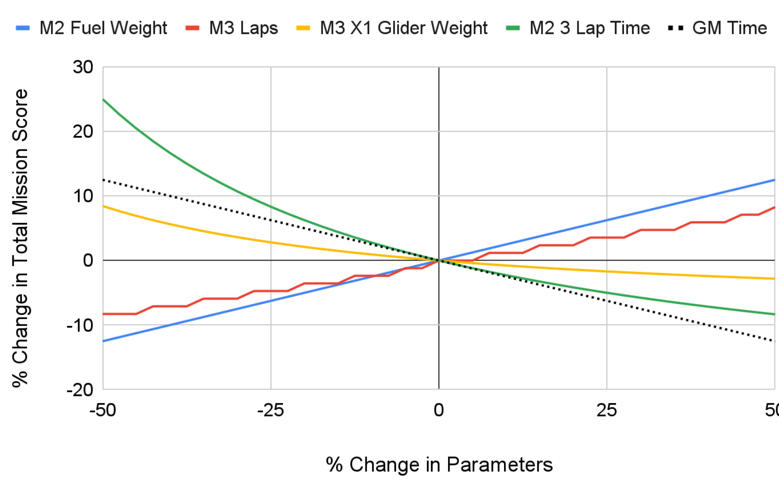

Figure 3. Sensitivity Analysis of Scoring Variables

3.3 Trade Studies & Mission Approach

The team conducted two trade studies to determine optimal aircraft parameters. The first focused on the importance of the glider in M3. We hypothesized that it might be beneficial to neglect the glider bonus points in favor of a faster aircraft, as speed impacts M2 and M3. However, we found that the bonus glider points far outweigh the extra laps that can be done. Using data from previous competitions, we concluded that the fastest plane without a glider could fly 14 laps in 5 minutes, while adding the glider would limit the plane to 10 laps due to extra weight and drag. The minimum 4.54 equivalent laps from the bonus points result in comparable scores, so we decided to pursue the bonus box points for M3. Leaving us to optimize M2 and GM.

Using MATLAB, XFLR, and previous teams' data, the team also developed a program to analyze the tradeoff between fuel weight and aircraft speed for M2. We found that around 8 pounds was the most optimal payload weight. Past this, the extra weight slows down the aircraft significantly, resulting in a lower M2 score. Increasing the total payload also reduced the GM score due to the need for more complex supports and connections to carry the extra weight. We found that beyond 8 pounds, a third bottle is needed to reduce wing weight, leading to a sharp decrease in GM score. Therefore, we decided that carrying 7 pounds for M2 would maximize the GM score while still achieving a competitive M2 score.

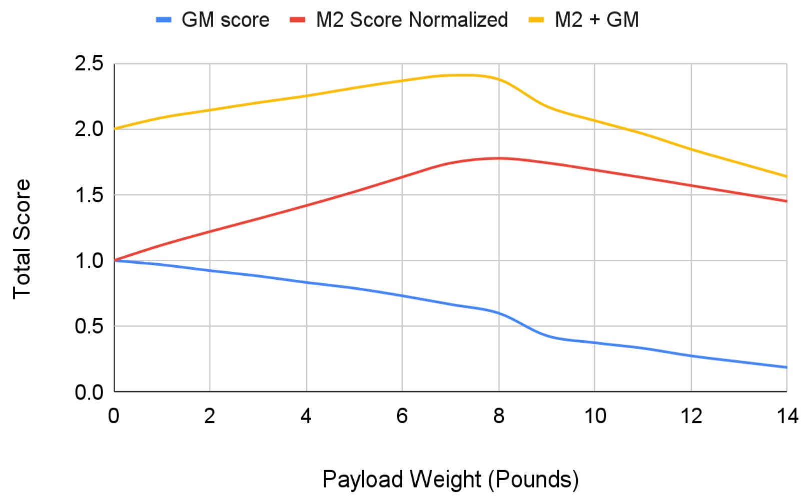

Figure 4. M2 Trade Study

With this configuration, our plane is designed to carry a 7-pound payload and fly 3 laps in 88 seconds for M2. For M3, we plan to fly 8 laps and go for the additional bonus box points from the glider. With our predicted maximum parameters, this configuration will give us a max flight score of 6.44.

3.4 Preliminary Design

The team decided on the design of the aircraft based on sensitivity analysis, trade studies, constraints from the rules, and mission scoring to create a high-scoring concept. We aimed to maximize factors such as L/D, stability, and velocity while minimizing the number of fuel tanks. To achieve this, we chose a monoplane high-wing configuration to reduce drag and enhance roll stability, aligning the fuel tank weight with the center of gravity for better performance. The wing has a span of 72 inches with a root chord of 17.2 inches and a tip chord of 10.3 inches, giving a mean aerodynamic chord (MAC) of 15.9 inches. It features a 0.6 taper ratio starting 20 inches from the root chord to secure structural integrity for the fuel tank pylon and achieve a semi-elliptical lift distribution. After evaluating previous airfoils used in competition, we concluded that the NACA 4412 airfoil would optimize L/D for M2, providing a Cl/CD of 1.38 at a Reynolds number of 630,000.

The aircraft features a conventional tail mounted to the fuselage due to the manufacturability and stability compared to H-tail and V-tail configurations. The horizontal tail has a chord length of 10 in. and a span of 22 in., while the vertical tail has a chord length of 10 in. and a span of 11 in. The tail dimensions were determined using sizing equations and conducting stability analysis.

Since the competition has no required internal payload, the fuselage is a 3.5 x 3.5 x 54 in. rounded rectangular body designed to reduce drag while housing the electronics and extending to the tails for structural support. The team chose a tricycle landing gear configuration for suitable ground clearance for the glider and access to the fuel tanks, along with a single propeller tractor configuration to minimize weight and maximize efficiency. Using manufacturer static thrust data, we concluded that the Scorpion A-5025 415kV motor with a 19x10E propeller provides sufficient thrust to lift off and carry our desired fuel tank weight. The motor is powered by a 4200 mAh 6s Li-Po battery, which conforms to the 100 Wh limit and provides 6 minutes of flight for M3.

To fulfill the missions, the team has decided that the fuel tanks will be standard 16.9 oz Coke bottles. An ABS plastic fairing and pylon will be created and attached to the wing to reduce parasitic drag and attach the fuel tanks. The glider was designed to minimize the amount of weight while providing enough wing area and lift to carry the electronics and ensure controllability from the flight controller. The glider is mounted underneath the fuselage with a wingspan of 22 inches and a chord of 4 inches. It features an H-tail that wraps around the fuselage for a stable mounting, and we will use the Speedybee F405 Flight Controller and GPS to meet M3's bonus point requirements.

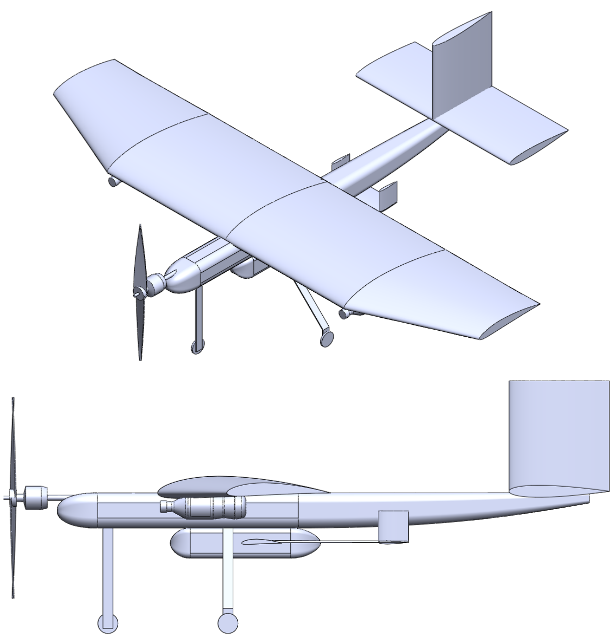

Figure 5. Preliminary Aircraft Design and Payload Mounting

IV. Manufacturing Plan

4.1 Manufacturing Flow

The manufacturing flow chart is shown in Figure 6 and outlines the iterative process for the design of the aircraft. Following the detailed design, the aircraft is manufactured and assessed through simulations and physical testing. In flight testing, the team will analyze drag, stability, power consumption, and overall performance to optimize the design.

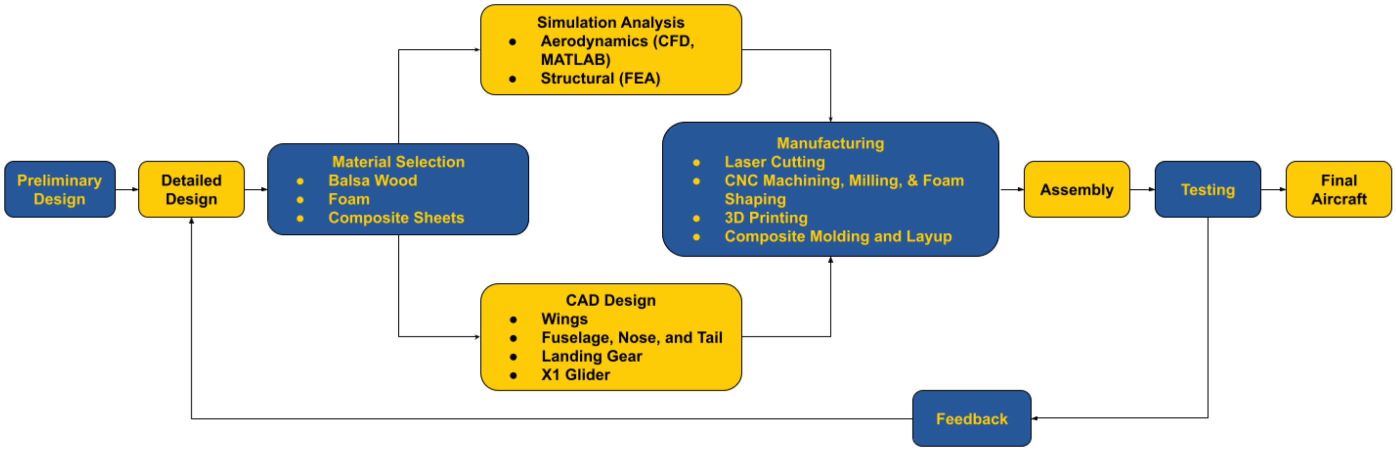

Fig 6. Manufacturing Flow Chart

4.2 Manufacturing Processes

The manufacturing plan for this year's aircraft involves creating the primary structural components, such as the wings, fuselage, tails, and landing gear, using a combination of fabrication techniques suited to their specific functions. The plan includes precise cutting methods like laser cutting and CNC machining for critical load-bearing components and intricate shapes. Lightweight materials such as balsa wood, foam, and composite sheets are selected based on the need to maintain structural integrity while reducing overall weight. To ensure aerodynamic performance, all wood structures will be covered in MonoKote film. Additive manufacturing, particularly 3D printing, will be used to produce custom parts that require complex geometries and quick design modifications.

Composite molding reinforces key structures like the landing gear and aerodynamic fairings through layering materials like carbon fiber or fiberglass in molds. Methods such as vacuum bagging and resin infusion ensure each component meets the necessary strength-to-weight ratio. This combination of processes ensures the aircraft is structurally sound and adaptable to varying mission configurations.

Once individual parts are produced, assembly involves fitting and securing these components using adhesives, mechanical fasteners, and reinforcements to ensure overall stability. The approach includes pre-assembling critical subsystems, like the wings and fuselage, in stages to facilitate easier inspection and integration into the final assembly. Each key component is designed to meet specific requirements for rigidity, aerodynamics, and modularity to accommodate the missions.

V. Test Planning

The aircraft performance is validated through a rigorous testing plan outlined in Table 4. Tests are divided into preliminary, ground, and flight tests. Preliminary tests are used to determine initial design parameters for the aircraft. Ground tests are used to optimize structural components, ensure flight-readiness, and optimize GM. Flight tests are designed to collect aircraft data to collect data, validate performance calculations, and reiterate upon the aircraft design based on the new values.

Test	Subteam	Objective	Method
Preliminary			
Static Thrust	Propulsion	Measure thrust, current, and power for various motor, propeller, ESC, and battery configurations. Validate calculations performed using MotoCalc and eCalc.	Use a thrust stand to tabulate values for different configurations at various RPM.
Ground			
Wingtip Loading	Structures	Measure maximum wing deflection under expected loads.	Attach wing structure to wingtip loading apparatus. Load weights up to maximum expected load in flight.
Landing Gear	Structures	Measure landing gear response to expected loads. Compare to FEA analysis.	Perform drop tests using a representative load and monitor structural response.
Flight Controller	Payload	Validate functionality of autonomous controls.	Monitor telemetry at ground level and verify glider response to changes in attitude and altitude.
Ground Mission	Payload	Simulate ground mission. Optimize procedure to maximize efficiency.	Iterate through ground mission requirements including loading and unloading of fuel tanks and glider.
Flight			
Takeoff Distance	Aerodynamics	Ensure aircraft is capable of taking off within expected distance.	Measure aircraft takeoff distance.
Endurance	Aerodynamics	Monitor battery usage in M3 configuration to determine optimal cruise speed to maximize number of laps.	Measure battery capacity after M3 test flight.
Cruise	Aerodynamics	Validate cruise speed in M1 and M2 configuration and compare to expected calculations. Evaluate drag and motor performance.	Collect flight data at cruise conditions using telemetry.
Glider Drop	Aerodynamics	Monitor glider performance and autonomy.	Drop glider from required height. Tabulate time of descent and proximity to desired location.

Table 4. Testing Plan with Objectives and Methods