ILLINOIS INSTITUTE OF TECHNOLOGY
2022-23 AIAA DBF PROPOSAL

1 Executive Summary

This proposal serves to outline the design, manufacturing, and testing processes of the Illinois Institute of Technology (IIT) 2022-23 DBF team. The team's objective is to design and manufacture an electronic warfare aircraft for various surveillance and signal jamming missions. DBF's mission requirements dictate that the aircraft must fit inside an airline checked shipping box with maximum total dimensions of 62 inches. Additionally, the aircraft must complete all three missions and a ground mission as described in Table 3.1. To maximize overall score, the team first conducted sensitivity analyses based on maximum electronic package weight that can be carried for Mission 2 and the length of jamming antenna that can accommodated for Mission 3. The results of this analysis were incorporated into the team's preliminary design.

An overview of the team's structure is shown in Section 2. Following this, Section 3 discusses the approach used to develop a design as well as the individual sub-teams' methods. The manufacturing methods are explained in Section 4. Finally, the aircraft will go through a testing regime defined in Section 5.

2 Management Summary

IIT's team is student run and has a faculty advisor present to provide necessary guidance. The team is composed of multiple sub-teams that are each responsible for a major design component of the aircraft. Table 2.1 describes the roles and skills utilized by each sub-team. A sub-team is led by a team lead who reports to the Project Manager and Lead Engineer (see Figure 2.1). The Lead Engineer oversees all components of the design and ensures cohesion between all sub-team decisions. The Lead Engineer also reports progress and design decisions to the Project Manager. The Project Manager is responsible for ensuring the design progress stays on track, deadlines are being met, and team leads are focusing resources on appropriate tasks.

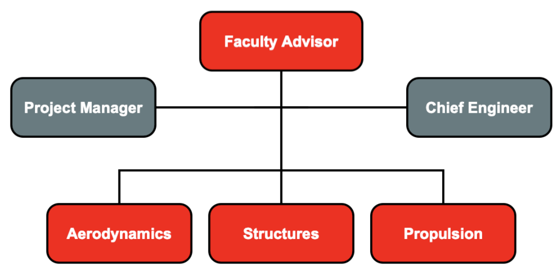


Figure 2.1 – Illinois Tech's team structure.

Table 2.1 – Description and skills utilized and learned for each sub-team.

Sub-team	Responsibilities	Associated Skills
Aerodynamics	Design of lifting bodies, aircraft sizing, aerodynamic performance, and stability analysis.	• Aerodynamics and flight mechanics • XFLR5 and related CFD software
Propulsion	Selection of motor/battery combination, setup of remote control systems, and flight data analysis.	• Propulsion sizing tools • Electrical design • System analysis and feedback control
Structures	Design of aircraft structures, mechanical systems, and shipping container along with material selection.	• Structural mechanics • SolidWorks and FEA software

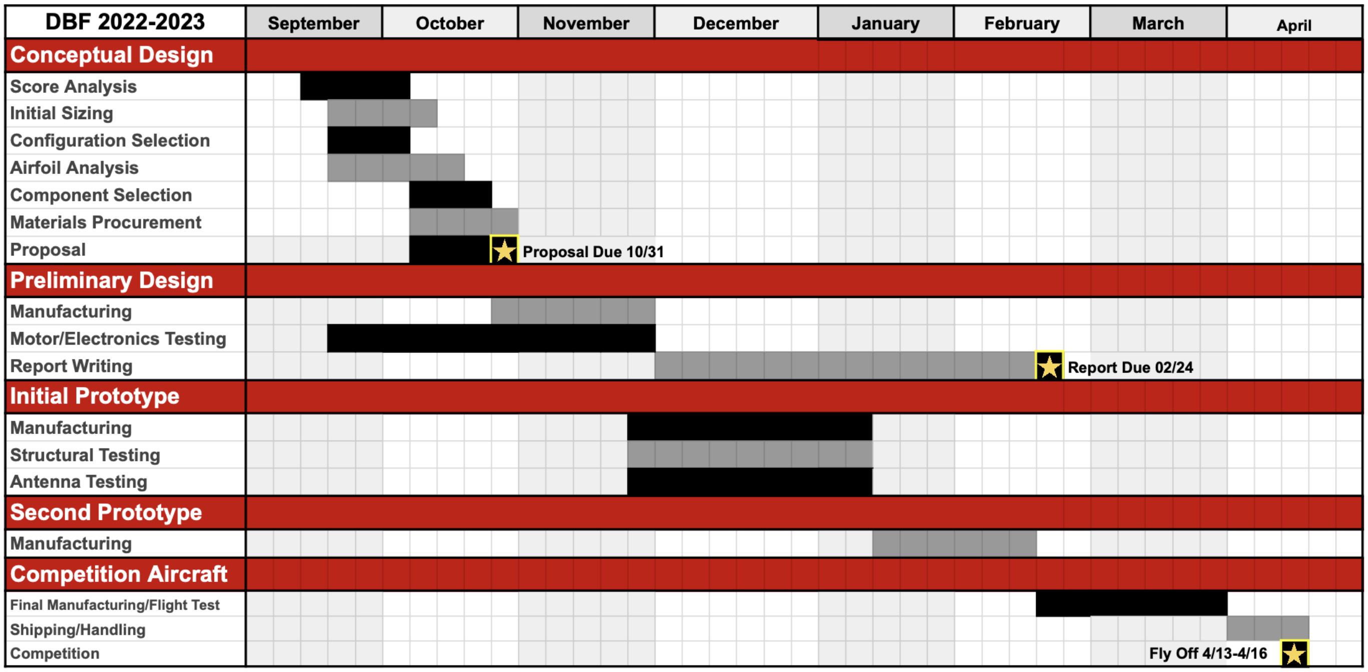


Figure 2.2 – Illinois Tech Team Milestone Chart

A Gantt chart, as shown in Figure 2.2, is maintained by the Project Manager to monitor project status and distribute resources accordingly. The schedule serves to determine task completion times, delays, and appropriate task order.

2.1 Budget

The project will be funded by the Illinois Institute of Technology Student Activity Fund (IIT-SAF) and from individual members of the team. IIT-SAF will fund the entirety of materials and components for testing, design, and approximately 70% of the costs associated with travel to the competition. A summary of the expected expenses are shown in Table 2.2. The necessary machines and tools are available in IIT's Idea Shop and the AIAA-IIT lab which has been furnished by IIT-SAF.

Table 2.2 – Proposed Budget with Funding Sources

Expenses	Description	Cost	Funding Source
Structural materials	Balsa, plywood, adhesives, hardware	$1120	100% IIT-SAF
Propulsion system	Motors, ESC, battery, propellers	$385	100% IIT-SAF
Control system	Wiring, servos, RC controller, receiver	$130	100% IIT-SAF
Miscellaneous	Landing gear, monokote, tools	$225	100% IIT-SAF
Air Travel	7 Students, $450 per person	$3150	30% Self. 70% IIT-SAF
Hotel	3 rooms for 4 nights	$1800	30% Self. 70% IIT-SAF
Transportation	2 Cars for 5 days + gas	$1500	30% Self. 70% IIT-SAF
Total		**$8310**	

3 Conceptual Design Approach

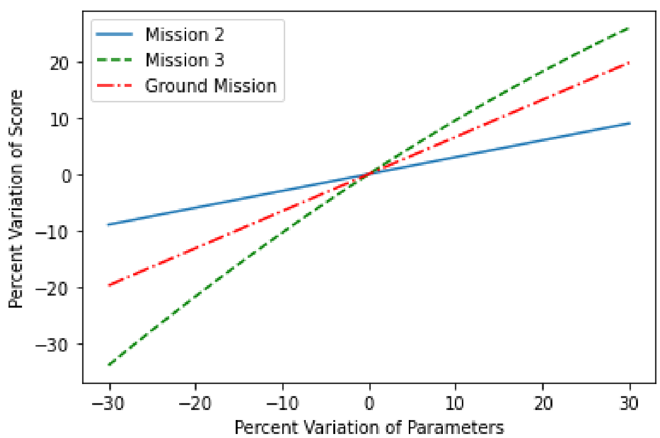
The aircraft must be capable of being compactly stored, swiftly constructed, and fly various electronic warfare missions. The designed aircraft must perform three flight missions and one ground mission. Table 3.1 provides a summary of each mission requirement.

Table 3.1 – Mission Requirements and Subsystem Design

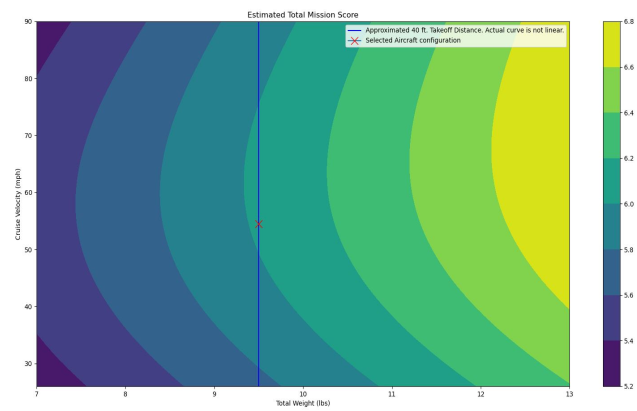
Mission	1- Test Flight	2-Assembly	3-Antenna Flight	4-Ground Mission
Requirement Summary	No payload. Complete 3 laps in 5 minutes.	Assemble the aircraft and fly as many laps as possible in 10 minutes. The electronics package must fly with the plane.	Fly 3 laps as fast as possible with the antenna attached.	Structural load testing, via wing-tip tes
Design Objective	• Wing and propulsion system design must enable take-off in 60 ft. without EW payload and provide minimum 26 mph average flight velocity.	• Wing and tail boom assembly must be simple and be quick to build, allowing for more flight time. • Wing and tail must be secure during flight. • Wing and Propulsion design should maximize cruise velocity to achieve the highest amount of laps in the allotted time. • Tail control surfaces should have sufficient volume to manage the increased weight of Electronic payload and still perform attitude control duties.	• Builds on M2's requirements. • Antenna must be mounted on wing. • Tail control surfaces should be capable of fixed deflection to counteract surplus drag and related moments caused by the antenna.	• Structure should aim to maximize wing strength to weight ratio to allow for higher loading weight relative to aircraft weight
Scoring	$M_1 = 1.0$ (Successful)	$M_2 = 1 + \frac{(Laps * W_{Payload})_{IIT}}{(Laps * W_{Payload})_{max}}$	$M_3 = 2 + \frac{(L_{antenna}/t)_{IIT}}{(L_{antenna}/t)_{max}}$	$GM = \frac{(W_{total}/W_{max})_{IIT}}{(W_{total}/W_{max})_{max}}$

3.1 Configuration Selection

A sensitivity analysis was performed to determine the effect of design parameters on score. Based on Figure 3.1a and 3.1b it was found that a high thrust, high payload configuration is ideal for maximizing score. It was determined that a single motor, high-wing monoplane with a conventional tail would be the most stable and highest scoring configuration. The monoplane configuration was chosen due to its low drag, low weight, and ease of manufacture. A single motor was chosen to permit increased structural strength of the wing, necessary for the Ground Mission. A high wing configuration provides higher aerodynamic stability and increases propeller sizing options.



(a) Parameter Score Variation

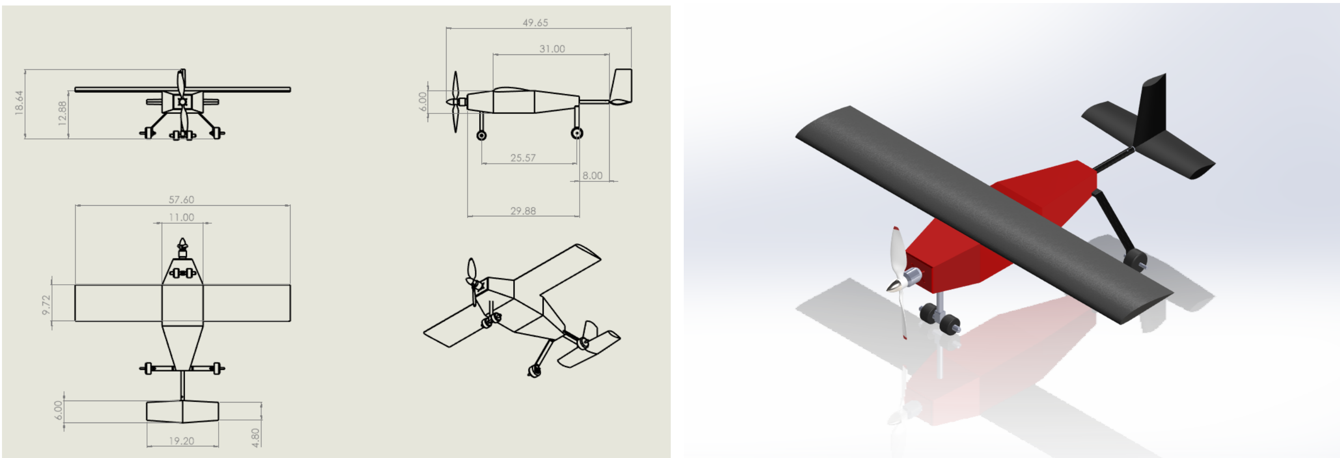


(b) Relating Critical Design Parameters. Line of 40 ft. Maximum takeoff distance is a linear approximation.

Figure 3.1 – Score Analysis

3.2 Preliminary Sizing

Wing and tail dimensions were determined using XFLR5, an X-FOIL based aircraft design and analysis software. The maximum wing span of 4.8 ft according to box dimensions was selected with a rectangular wing planform and chord of 9.7 in. The main wing incorporates the Clark Y airfoil, as XFLR5 analysis showed that this airfoil produced the least drag during cruise conditions. It also produced the most desirable stability characteristics of the airfoils analyzed. With the current aircraft total weight and wing area, the wing loading is approximately 2.5 lbs/ft^2. Using estimated takeoff speed and average acceleration during ground roll, the aircraft can takeoff within the required 60 feet. A conventional aft tail configuration was selected for the tail section. Using the dimensions of the main wing and historical data, the horizontal and vertical stabilizers were sized. The horizontal stabilizer has an area of 115 in^2 and uses an inverted E211 airfoil, while the vertical stabilizer area is 44.7 in^2 with a NACA 0012 airfoil. The static margin was calculated at 22.9% with the payload and 25.8% without allowing the aircraft to remain longitudinally stable despite differing centers of gravity for Missions 1 and 2.



(a) Aircraft 2D-Sketch **(b)** Aircraft 3D-CAD

Figure 3.2 – Preliminary Design

Table 3.2 – Preliminary Aircraft Dimensions

Empty Weight	6.65 lb	Payload Weight	2.85 lb
Structural Weight	3.68 lb	Total Weight	9.50 lb
Wing Area	560 in^2	Wingspan	57.6 in
Horizontal Tail Area	115 in^2	Horizontal Tail Span	19.2 in
Vertical Tail Area	44.7 in^2	Vertical Tail Height	8.76 in
Fuselage Length	30 in	Fuselage Width	11 in

3.3 Propulsion Selection

Propulsion requirements were determined from the desired thrust-to-weight ratio and endurance. The required thrust for takeoff and cruise speeds were determined based on the aerodynamic parameters and structural limitations of the preliminary aircraft design. eCalc, a propulsion system analysis software, was used to find battery, propeller, and motor configurations that met the targeted thrust, cruise speed, and endurance requirements. A selection matrix was used to determine the motor for the aircraft, shown in Table 3.3. All configurations are predicted to have a thrust-to-weight ratio above 1.00 and mixed flight time of at least ten minutes.

Criteria	Points	Power 60A	SII-4020	X5-400
T/W	45	3	1	2
Flight Time	30	2	3	1
Weight	35	2	1	3
Total	100	265	170	225

Table 3.3 – Propulsion Selection Matrix

3.4 Wing and Jamming Antenna Integration

With the requirement of detachable wing sections designed for rapid assembly and high structural strength, a fast attachment method was necessary for mounting the wings. Side mounting of the wings was chosen to maximize available wingspan and allow for ease of wing section manufacturing. Each wing will be mounted by sliding the two wing spars into two hollow shafts in the fuselage. Locking pins will secure the wing to the fuselage while allowing for strong structural coupling. Similarly, the antenna (see Figure 3.3) will be mounted using a 3D-printed component that will slot into the hollow carbon fiber spars at the wingtips. An adapter must be made for each side, as the spars are not of the same inner diameter. A counterweight will be used on the opposite wingtip to improve lateral stability. Additional testing must be done to test acceptable lengths based on final design, wind interference, and manufacturing.

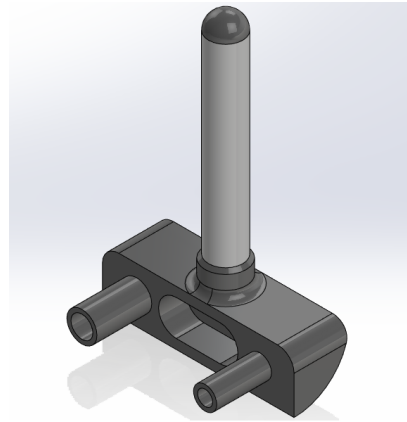


Figure 3.3 – Antenna

4 Manufacturing Plan

The team's manufacturing process is displayed in Figure 4.1. The team will be utilizing a CNC mill, laser cutter, and 3D printer to manufacture components. The aircraft will be constructed using balsa and plywood with a Monokote skin. The team will manufacture two proof of flight aircraft to determine the optimum aircraft system design and configuration. The Lead Engineer assists the structures sub-team in designing components based off of data provided by the sub-team leads. Design drawings are shared with all team members for manufacturing and assembly.

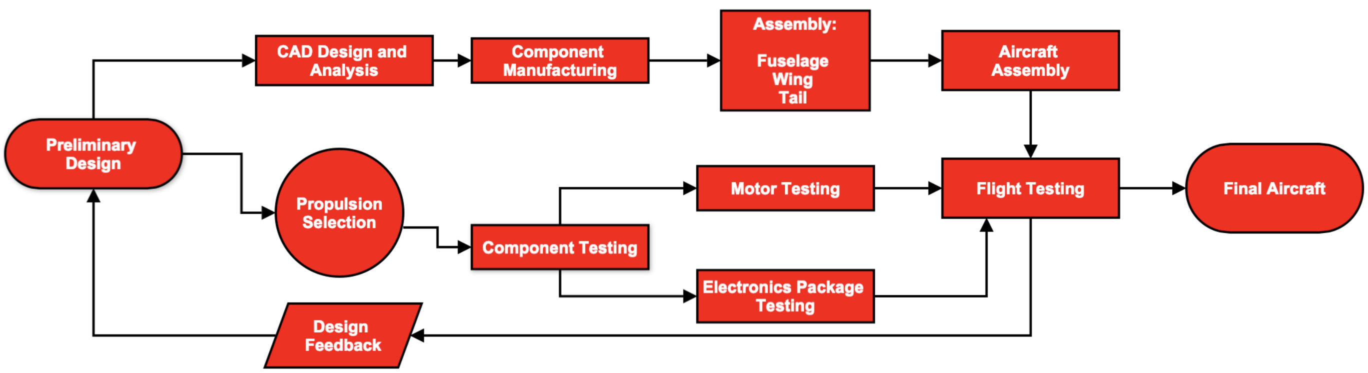


Figure 4.1 – Manufacturing Flow Chart

5 Test Planning

All components will be tested prior to the contest during flight testing. The propulsion system will be evaluated first on a static motor test stand prior to test flights. In-flight data will be collected using the electronic speed controller to record the data points. A wing tip test will be conducted by attaching the aircraft to a ground-test fixture, placing the antenna on each section at a time. The proof of concept test flight will validate the aircraft configuration and wing sizing. Following each prototype cycle, results will be evaluated and improvements implemented into future iterations. Structural components will be evaluated through in-lab testing to verify structural integrity under anticipated in-flight loads. The final flight test will be conducted with the competition aircraft and will fully simulate all missions to ensure expected performance goals are met. Key performance parameters of interest are stability, lap time, and acceptable antenna lengths.