Design, Build, Fly (DBF)

Final Report

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DISCLAIMER

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ABSTRACT

The Design, Build, Fly (DBF) competition, hosted annually by the American Institute of Aeronautics and Astronautics (AIAA), challenges teams to design, manufacture, and test a remote-controlled aircraft under a unique set of mission requirements. This year's competition emphasized captive carry and autonomous capabilities, which initially shaped the aircraft's design.

The aircraft was developed to meet AIAA DBF constraints, including a maximum 6-foot wingspan, payload-carrying capability, and autonomous flight functionality. A structured design process was employed, incorporating trade studies to optimize speed, weight, and structural integrity. The final airframe consists of balsa wood, basswood, and carbon fiber, chosen for their balance of strength and low weight. The propulsion is provided by a dual-propeller system, enabling efficient power performance while supporting a maximum takeoff weight of approximately 17 lbs.

Although the team did not qualify for competition, a revised project scope was established to further develop the aircraft's autonomous capabilities. With the removal of the captive-carry glider, the focus has shifted to making the mothership fully autonomous. ArduPilot firmware, integrated with GroundControl software, facilitates mission programming and autonomous flight operations. Flight testing has evaluated stability, maneuverability, and landing precision across various autonomous flight modes, validating the aircraft's adaptability and performance.

Significant progress has been made in manufacturing and assembly, with the aircraft structure nearly complete. The remaining work involves finalizing software integration, completing the wiring, and applying the Monokote covering to the airframe. Once these final steps are completed, the aircraft will be ready for its first flight, marking a major milestone in the team's development process.

ACKNOWLEDGEMENTS

This year's DBF team owes much of its success to the support of several key individuals and groups. These contributors include, but are not limited to, the following:

Prof. Özcan Ertem - Ertem played a significant role in the design and manufacturing aspects of the project, contributing to the overall logistics and ensuring that tasks were completed efficiently within the team. As an aerospace professor, his expertise provided valuable insight into the technical aspects of the project.

John Greeven – John was an invaluable source of moral support and guidance throughout the project. As the capstone advisor, he helped steer the team toward success with his patience, expertise, and encouragement.

Solar Plane Team – The OSU Solar Plane team generously shared their space in the AIAA lab with DBF. They were always willing to provide advice and lend tools, which played a crucial role in completing the project.

OSU AIAA – The OSU chapter of the American Institute of Aeronautics and Astronautics (AIAA) was a significant source of funding for this year's project. Without their financial backing, the project would not have been feasible.

OSGC – The Oregon Space Grant Consortium (OSGC) provided vital funds that allowed DBF to acquire the materials and technologies necessary for a successful project. OSGC's mission to promote aerospace within all communities helped the team access valuable outreach opportunities.

AIAA – As the sponsor of the DBF competition and the overseeing body of the OSU chapter, AIAA is fundamental to the existence of this team. Their continuous support ensures that students remain engaged with aerospace by providing resources, learning opportunities, and connections to the industry.

OSU – Oregon State University supported this year's DBF team by providing both the necessary space and funding, encouraging student involvement in aerospace-based capstone projects.

Volunteers – The team greatly benefited from the support of volunteers, whose contributions in assisting with assembly, testing, and design were critical to the project's success. Their help allowed the team to overcome challenges and complete tasks on time.

Past DBF Teams – Previous DBF teams set a solid foundation for this year's group through well-documented information and lessons learned, which were essential in ensuring the project's continuity and success.

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1 BACKGROUND

1.1 Introduction

The American Institute of Aeronautics and Astronautics (AIAA) Design, Build, Fly (DBF) competition is an annual contest that is designed to provide university students from across the United States, and the world, with an opportunity to be involved in every step of the aircraft design and development process. Oregon State University (OSU) houses a student chapter of the AIAA organization, which provides OSU students with the opportunity to compete in the competition every year. Unlike some other aerospace competitions that highlight theoretical problems or challenges, the DBF competition is typically based on a real-world problem. This year, the competition focused on the X-1 plane experiments, which were tests that investigated the viability of a supersonic aircraft. The unique part of these experiments was the fact that the X-1 aircraft was initially dropped from the bomb bay of a bomber aircraft, as opposed to taking off under its own power. This year's competition seeks to model those same conditions seen in the original X-1 plane experiments by requiring teams to design a "mother plane" that drops a smaller glider from beneath the fuselage. This design challenge presents a unique problem that replicates one seen commonly in the aerospace industry: how can an aircraft be tested in real-world conditions without the hazards and costs associated with independent take-off?

The OSU DBF team seeks to answer that question by designing and fabricating a high-performance aircraft capable of navigating various mission profiles designed to test the vehicle's endurance, maneuverability, and flight handling; with the ultimate objective of producing an aircraft that demonstrates superior capabilities and reliability within practical and cost-effective manufacturing constraints. The primary outcome of this project will be the completion of this aircraft, which will then be showcased to the Oregon State community, Oregon Space Grant Consortium, and members of the Corvallis community. This experience will improve the university's recognition in aerospace and engineering circles, and open up networking opportunities for both the university and the team.

In addition, the project encourages each team member to innovate by experimenting with materials and design configurations to maximize performance during the mission profiles, fostering creative problem-solving skills. This initiative engages students in research on existing aircraft technology and encourages advancements in aerospace design. The cycle of design, testing, analysis, and redesign cultivates critical thinking and a scientific approach, reinforcing engineering fundamentals while pushing the team to explore new solutions. This project also bridges the gap between classroom theory and real-world applications, allowing team members to apply principles of aerodynamics, electronics, and mechanical design. It will help to develop vital professional skills including team collaboration, communication, project management, and technical documentation in order to prepare the team for roles in aerospace and engineering.

Furthermore, this year's DBF team focused on developing an aircraft that is capable of autonomous flight, which is currently a highly-discussed topic in the wider aerospace industry. Those involved in the aerospace community, both in the private and public sectors, are looking to autonomous flight as the next big step in the development of the industry. Aircraft with either partially or fully autonomous flight capabilities are becoming increasingly ubiquitous across nearly every aspect of aerospace applications, and the team seeks to emulate that integration through the development of its own autonomous aircraft, capable of both manual and automated control.

1.2 Project Scope

The scope of this project is to demonstrate the deployment of a student-designed and fabricated, unmanned, electric powered RC aircraft and its capabilities through a series of unique mission profiles. These mission profiles are specified by the AIAA competition Design, Build, Fly (DBF), where the team's plan was to ultimately travel to and compete in to demonstrate the aircraft and its capabilities [1].

The scoring of this competition is based on several variables throughout the three unique missions:

1. The objective of **Mission 1** is to fly the aircraft at least three times around the track, completing a 360 degree turn along the backstretch per each lap, within a 5-minute window (course layout shown in **Figure 1**). This mission is graded on completion and is worth 1 point total [2].

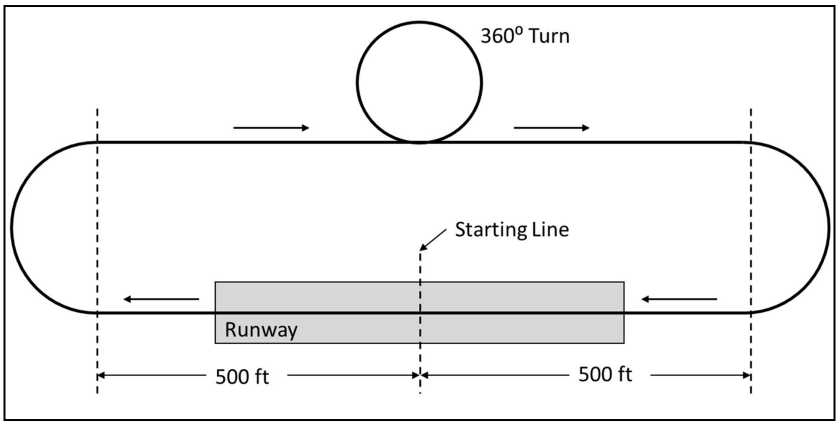


Figure 1: Course layout and flight path map

2. The objective of **Mission 2** is to complete the flight path seen in Figure A 3 times within a 5-minute window, while transporting a payload (specified as fuel tanks). This mission is graded in two parts: 1 point goes to completing the minimum flight path within the 5-minute window, and a fraction of the additional point is awarded as a function of carried fuel weight and number of laps completed over the best-performing team. This means that the best performing team is awarded an extra point, and each team after them is awarded a fraction of that point depending on their performance in comparison [2].
3. **Mission 3** is split into multiple aircraft missions:
    a. The mothership (main RC aircraft) must complete 1 flight path seen in **Figure 1** holding empty fuel tanks and a custom-built glider (known as the X-1 glider) before deploying the glider, completing (at least) one more lap and successfully landing.
    b. The X-1 glider must deploy from the mothership mid-flight, turn on strobe lights, and autonomously turn 180 degrees before landing in a specified target landing area before the mothership lands.

    This mission is graded as 2 points in completing the minimum flight path and successful deployment and landing, while bonus points are awarded for the X-1 glider landing within specific parts of the landing target. These bonus points are awarded as a function of bonus points, number of laps, and glider weight per fraction of the best-performing team [2].

This point distribution is broken down into more detail in **Table 1.**

Table 1: Mission, Scoring, Requirements, and Design Considerations

Mission	Scoring	Requirements	Sub-System Design Considerations
M1: Delivery	1	Aircraft must be put in flight configuration within 5 min then fly at least 3 laps within 5 min.	Aircraft's battery installation is simple and enables rapid deployment.
M2: Captive Carry	$1+\frac{N\left[\frac{W_{fuel}}{t_{3laps}}\right]}{Max\left[\frac{W_{fuel}}{t_{3laps}}\right]}$	The entire payload must be attached within 5 min. There is 5 min to fly at least 3 laps.	Payload and battery must be loaded quickly, and the aircraft supports payload weight.
M3: X1 Launch	$2+\frac{N\left[n_{laps}+\left(\frac{Bonus}{W_{x1}}\right)\right]}{Max\left[n_{laps}+\left(\frac{Bonus}{W_{x1}}\right)\right]}$	X-1 glider must attach to aircraft along with payload which can be empty, within 5 min. After at least 1 lap, autonomous glider must be deployed from 200-400 ft and land within 5 min.	Aircraft capable of carrying underbelly glider.
Ground Mission: X-1 Demo	$\frac{M_{in}[T_{mission}]}{N[T_{mission}]}$	Install all pylons, fuel tanks, X-1 vehicle, and X-1 ground launch as fast as possible. Aircraft must stand on landing gears during demonstration.	Clearance, mechanisms, and hatches ensure ease of installation.

During week 9 of the first term of this project, the team was notified that the cutoff for the AIAA DBF competition was narrowly missed. As a result, the project scope was adjusted, reevaluating priorities to identify key aspects for future progress. These adjustments included:

1. Removing the X-1 glider from the project scope,
2. Integrating the autonomous abilities originally designed to be deployed in the X-1 glider into the mothership, and
3. Designing the mothership without external payload carrying mounts, however, keeping the ability to carry approximately 8 lbs of payload with the wing design.

Due to these changes, the non-competing project scope is to design, build, and deploy a student-fabricated RC aircraft with the capabilities of autonomous flight and landing while adhering to most competition guidelines and safety regulations.

2 DESIGN PROCESS

As with any design process, the first step of the project was an in-depth review of the customer requirements and specifications. Due to the team's participation in the AIAA Design, Build, Fly competition, the team did not have a traditional "customer;" however, the competition establishes specific design requirements that serve as guiding constraints. These requirements define key performance criteria and influence critical design decisions, ensuring compliance with competition objectives. In addition, the rules and regulations of the competition create an overall envelope of requirements that teams are constrained within, but the teams are free to design individual and unique solutions that complete each objective.

In order to begin this process, the team created a House of Quality diagram that listed out each of the customer requirements and engineering specifications described by the competition ruleset. The customer requirements described each of the non-numerical aspects of the design, such as autonomous flight capabilities and ease of assembly/repair, while the engineering specifications described the numerical aspects of the design, such as wingspan and maximum take-off weight. With each of these specifications in mind, the team assigned weighted values to each line item and compared the resulting table. Using the table outputs, the team could analytically determine which of the requirements was more important to the success of the project, weighted relatively to the overall competition.

Project:	DBF
Date:	3/02/2024
Team Members:	Miguel, Ahmed, Adael, Jack, RJ, Henry

ES #	Engineering Specifications (auto-entered)								
1	Width of Wings(ft)								
2	Weight of Mothership (lbs)	^							
3	Pitch and Roll and Yaw within ±5°	v	v						
4	Weight of Payloads (oz)	+	-	^					
5	Cost ($)	+	-	+	+				
6	Ease of Assembly and Repair (sec)	+	+	+		+			
7	Accurate Waypoints (within 1 meter)	-	+		^	+	-		
8	Thrust (N)	+	^	-	+	+	-	v	
9	Lift (N)	^	^	+	^	+	+	-	^

Engineering Specifications (ES)

	Customer Requirements (CR)	Customer Weights	Width of Wings(ft)	Weight of Mothership (lbs)	Weight of Payloads (oz)	Pitch and Roll and Yaw within ±5°	Cost ($)	Ease of Assembly and Repair (sec)	Accurate Waypoints (within 1 meter)	Thrust (N)	Lift (N)
		Direction	≥	≤	T	≤	≤	≤	≤	≥	T
1	Max 6 foot Wingspan	5	9	3			3	1		9	9
2	Max 55lbs for Mothership	2	3	9	3		1	1		9	9
3	Fuel Tanks	4	1	3	9		1			3	3
4	Flight Course	2				9			3		
5	Stay Within Budget	4	1	3	1		9			1	1
6	Easy to assemble and Repair	3	1				1	9			
7	Plane must fly autonomously	5	1			3	1		9		
8	Stable flight	5	9	9	1	1			3	3	3
	ES Ranking Calculations	Raw score	112	102	51	38	65	34	66	94	94
		Scaled	1.00	0.91	0.46	0.34	0.58	0.30	0.59	0.84	0.84
		Relative Weight	17%	16%	8%	6%	10%	5%	10%	14%	14%
		Rank	1	2	7	8	6	9	5	3	3
	Engineering Specification Units										
	Engineering Specification Targets										

Figure 2: House of Quality Diagram

In addition to the House of Quality diagram, the team established a Failure Modes and Effects Analysis that determined the aspects of the design that posed the highest risk to the aircraft. Each of the failure modes was based on either a critical aircraft function/subsystem or a key engineering specification, as shown in the table below:

Table 2: Complete FMEA Table

Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Severity (S)	Potential Causes and Mechanisms of Failure	Occurance (O)	Current Design Controls Test	Detection (D)	RPN	Recommended Action
1 - Wing Ribs Keep structural integrity of the wing	Crack or deformation	Loss of wing structural integrity, potential failure	6	High aerodynamic loads	4	Visual inspection, testing	5	120	Use reinforced materials, increase rib spacing
2 - Wing Spars Add strength to wing to combat bending loads	Bending or buckling	Wing collapse under load	9	Excessive loading, material failure	3	Load testing, strain gauges	4	108	Use high-strength materials, add redundancy
3 - Leading Edge Cut the air to minimize drag	Surface damage or detachment	Increased drag, reduced aerodynamic efficiency	7	Impact, poor attachment	3	Inspection during assembly	5	105	Use protective coating, enhance attachment methods
4 - Trailing Spar Support the wings shape	Fracture or misalignment	Deformation of wing shape	6	Manufacturing defect, fatigue	3	Dimensional inspection	6	108	Improve manufacturing QC, use fatigue-resistant materials
5 - CS Hinge Material	Hinge failure	Loss of control surface functionality	9	Wear and tear, material fatigue	4	Functional testing	5	180	Use wear-resistant materials, perform regular maintenance
6 - Wing Panel Outer section of the wing enclosing the ribs and spars	Cracks or delamination	Compromised aerodynamic performance	7	Material fatigue, stress	3	Visual inspection, ultrasonic testing	4	84	Use composite materials, improve bonding methods
7 - GPS Module Track the location of the aircraft	Signal loss or malfunction	Loss of location tracking	5	Electromagnetic interference, power failure	2	Signal quality monitoring	3	30	Ensure reliable power supply
8 - F405 Mini Wing Flight controller	Software or hardware failure	Loss of flight control functionality	10	Software bugs, electronic failure	2	Pre-flight diagnostics	3	60	Update firmware regularly, add redundant systems
9 - Wing Control Surfaces Control the aircraft	Bending or Buckling	Loss of flight control	9	Excessive loading, material failure	3	Visual inpection, loading tests	3	81	Use high-strength materials, add redundancy
10 - Landing Gear Base for the plane in contact with the ground from the wheels	Buckling or detachment	Aircraft instability during landing or takeoff	9	Overload during landing, material fatigue	3	Stress testing, visual inspection	4	108	Use high-strength materials, ensure proper attachment
11 - Wheels Connect to landing gear and make contact with ground	Fracture or deformation	Loss of mobility on the ground	8	Impact during landing, wear and tear	4	Functional testing, visual inspection	5	160	Use durable materials, perform regular maintenance
12 - Propulsion system (motors and mounts)	Fracture or detachment	Loss of flight control and thrust	10	Excessive loading, material failure	2	Testing and pre-flight diagnostics	5	100	Add structural supports around mounts and additional ribs

By determining the highest risk failure modes, the team could prioritize those subsystems across the entire design process to ensure the best possible risk mitigation. This prioritization was combined with a series of trade studies across the different subsystems, which helped to determine the best design solution that would satisfy the customer requirements at the lowest possible risk. These trade studies allowed the team to compare different design options, prior to manufacturing, and establish which option would provide the best results. A trade study was conducted for each major subsystem of the aircraft, including but not limited to: propulsion system, wing shape/placement, landing gear style, and tail design. Each of these studies gave the team valuable insight into how different subsystems would affect the performance of the aircraft, as well as how different combinations of subsystem designs would work together.

Once each primary subsystem had been defined through thorough trade studies and analysis, the team transitioned into the more complete phase of the design process, which centered around the completion of a 3D CAD model, pictured below in **Figure 3**:

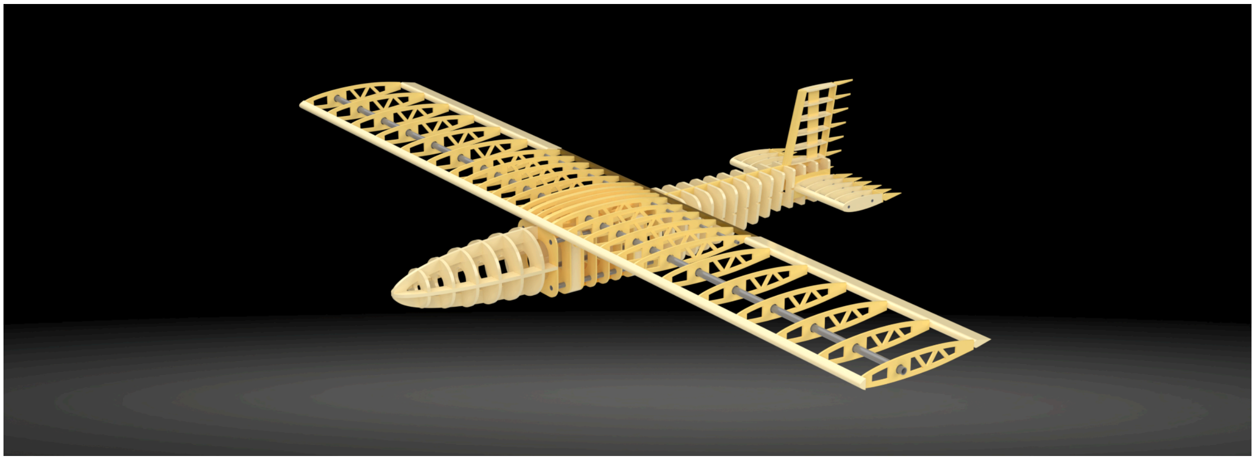


Figure 3: Completed CAD Model Rendering

This model would serve as the reference for almost all manufacturing processes during the build phase, largely due to the fact that over 85% of the airframe components on the aircraft were custom-designed by the team. This model was also used to develop a computational fluid dynamics analysis that modeled the aerodynamic performance of the aircraft at a standard cruising speed. This gave the team significant amounts of data regarding the theoretical in-flight performance of the aircraft and provided a visual representation of any turbulence that may affect the aircraft's flight.

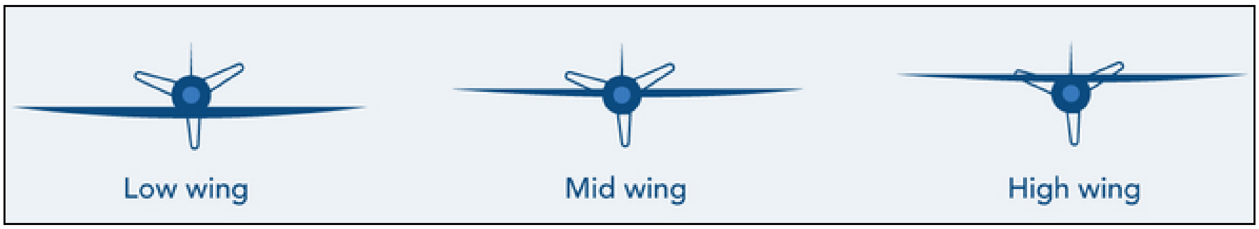
3 DESIGN PROPOSAL – First Term

The DBF competition required many design challenges including payload weight and the captive carry/ release of an autonomous glider. The team spent weeks on design options and through analysis, chose the design shown below. These design choices were split into 2 planes: the mothership and glider.

3.1 Mothership Preliminary Design

In designing the mother-plane, the team used decision matrices for the wings, tail and landing gear to decide what design options to continue with for each component. Shown below are concept designs proposed by the team and the analysis of choosing a system through matrices and reasoning.

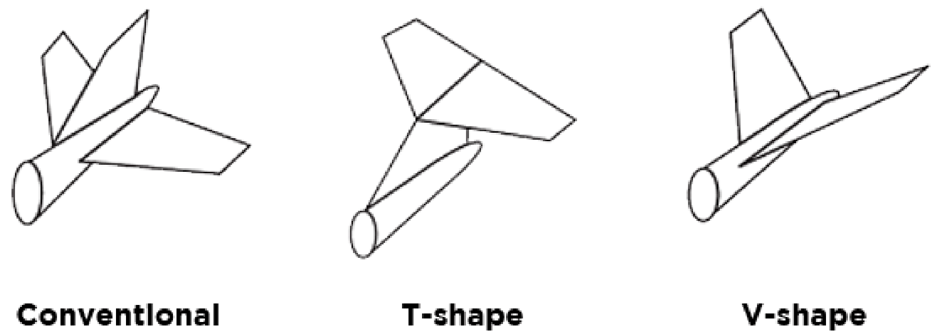
3.1.1 Wing Design Concepts



Wing Decision Matrix					
Criteria	**Weight**	**Standard**	**Low Wing**	**Mid Wing**	**High Wing**
Stability	4	0	0	-1	1
Lift to Weight Ratio	5	0	-1	-1	1
Aesthetic Appeal	2	0	1	-1	0
Ease of Control	5	0	-1	-1	1
Build Complexity	3	0	1	1	1
	Unweighted Sum:	0	0	-3	4
	Weighted Sum:	0	-5	-13	17

Figure 4: Wing Concepts and Wing Decision Matrix

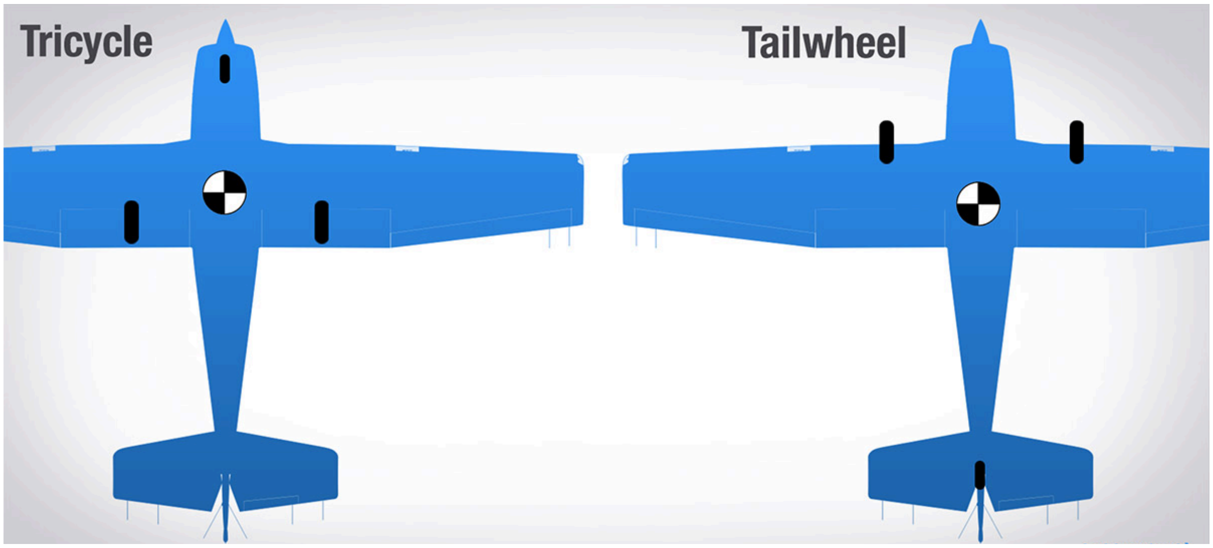
3.1.2 Tail Design Concepts



Tail Decision Matrix					
Criteria	**Weight**	**Standard**	**Conventional**	**T-Tail**	**V-Tail**
Stability	4	0	0	1	0
Control	5	0	1	0	-1
Aesthetic	2	0	0	1	1
Build Complexity	4	0	1	1	-1
Durability	3	0	1	0	-1
	Unweighted Sum:	0	3	3	-2
	Weighted Sum:	0	12	10	-10

Figure 5: Tail Concepts and Tail Decision Matrix

3.1.3 Landing Gear Design Concepts



Landing Gear Matrix					
Criteria	**Weight**	**Standard**	**Tail Dragger**	**Tri-Cycle**	**No Gear**
Plane Clearance	5	0	-1	1	1
Drag	3	0	0	-1	1
Aesthetic	1	0	-1	1	0
Build Complexity	3	0	-1	-1	0
Durability	5	0	-1	1	-1
	Unweighted Sum:	0	-4	1	1
	Weighted Sum:	0	-14	5	3

Figure 6: Landing Gear Concepts and Landing Gear Decision Matrix

Through the analysis of the competition requirements, a design maximizing lift, stability, and in-flight speed while minimizing drag is critical for an effective aircraft design. Thus, a high-wing design with a NASA/LANGLEY LS(1)-0413 (GA(W)-2) airfoil was selected for the preliminary design. A high-winged design optimizes stability and lift-to-drag ratio at an increased weight to best perform while carrying additional weight from the payload. This wing design also minimizes drag and therefore is optimal for increasing in-flight velocity, a variable which needs to be maximized to perform well during flight. The NASA/LANGLEY LS(1)0413 (GA(W)-2) airfoil was chosen with the same credentials in mind; this airfoil provides a low Reynolds Number, again optimizing stability and speed while minimizing drag. Shown below in **Figure 7** is the profile of this airfoil.

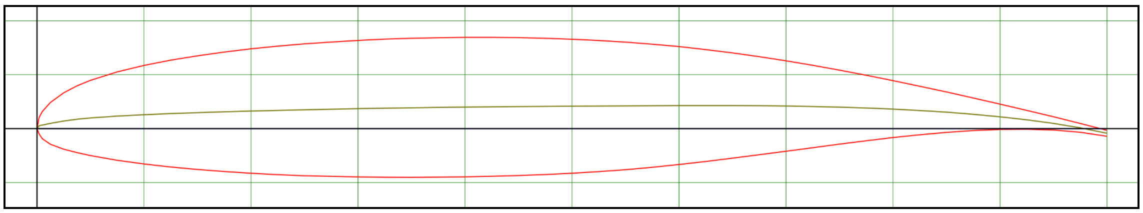


Figure 7: NASA/LANGLEY LS(1)0413 (GA(W)-2) Airfoil Profile

Providing a high stability and control, the traditional tail shape design was the clear choice. Manufacturability will be simple and easy, and controls will be simplified from a programming standpoint. The vertical and horizontal stabilizers will utilize the NACA 0012 airfoil, selected for its symmetric camber and low drag characteristics. Shown below in **Figure 8** is the profile of this airfoil.

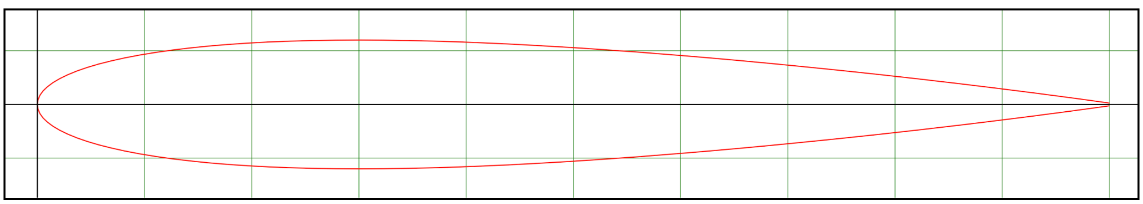


Figure 8: NACA 0012 Airfoil Profile

Additionally, the symmetric airfoil will provide a simple and functional base for control surfaces to be added with relative ease. With project requirements involving payload carrying and delivery, a high-winged design also eliminates the possibility of wing or ground interference as the plane carries and delivers the payloads through the tests. When choosing the landing gear, the tricycle-style landing gear was selected for its stability, high weight-bearing abilities, and ease of manufacturing.

From analysis, the preliminary design renderings can be seen below in **Figure 9.**

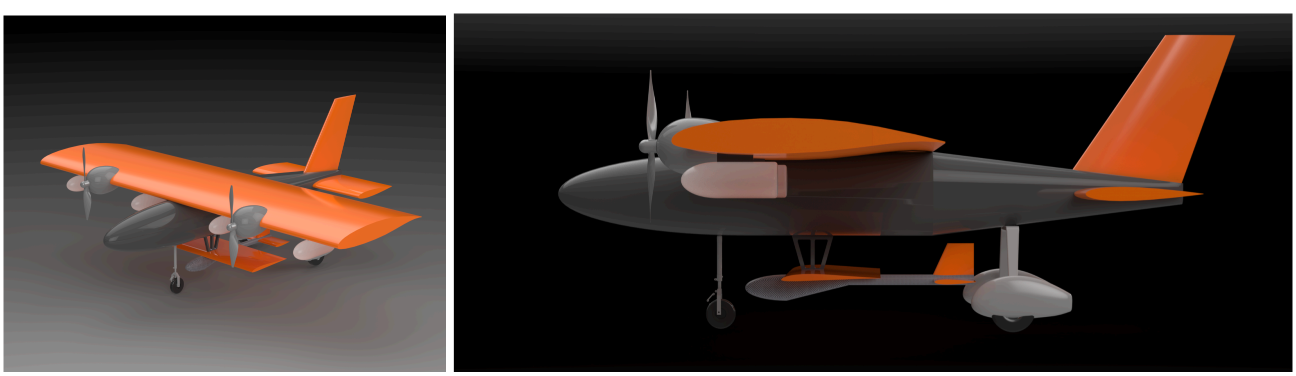


Figure 9: Preliminary aircraft design renderings

3.2 Glider Preliminary Design

In the preliminary design of the X-1 glider, the team is utilizing a similar high-wing design as the main aircraft to maximize stability and control during the glider's autonomous flight in M3. With a weight of 0.5 lbs. and a wingspan of 2 feet (24 inches), computations were performed to find a wing aspect ratio of 2.7:1 to provide the glider with the wing cube loading flight characteristics of a glider aircraft. A remote-controlled clip mechanism will be used to hold the X-1 glider to the fuselage of the main aircraft during M3 before glider deployment. This design will allow for quick attachment of the glider to the aircraft during M3 setup, and for seamless deployment when necessary. Modified software of an existing commercial unit will be used to map the location of the glider after deployment and autonomously land it within the designated 2.5-point landing zone.

4 Design Solution

Due to narrowly missing the cutoff for the AIAA DBF competition, the team redefined the project scope to focus on developing a fully autonomous RC aircraft while maintaining key elements of the original competition requirements. This shift led to several design modifications, including the removal of the X-1 glider, integration of autonomous capabilities directly into the mothership, and an airframe design optimized for payload capacity without external mounts. The updated objective remained to design, build, and test an aircraft that could execute autonomous flight and landing while adhering to most competition guidelines and safety regulations.

With this revised direction, the team conducted extensive design evaluations, focusing on aerodynamics, structural integrity, and avionics integration. Trade studies compared wing configurations, fuselage materials, and propulsion options to balance weight, performance, and manufacturability. Autonomous flight systems became a primary focus, requiring rigorous testing before full-scale implementation. This approach ensured that the final aircraft would meet the functional and performance criteria necessary for reliable autonomous operations.

4.1 Description of Solution

To validate the final design, the team employed a combination of analysis, computational simulations, flight testing and physical prototyping. Initial designs were run through Computational Fluid Dynamics (CFD) simulations to assess the aerodynamic performance of the design. While the design of the main aircraft commenced, a placeholder was needed to conduct flight tests with. An off-the-shelf aircraft was retrofitted with upgraded avionics to incorporate autonomous capabilities.

The purpose of this is to test a system without the risk of damaging the main aircraft. The autopilot system passed several tests to figure out configuration settings and capabilities. The autopilot is capable of stabilized flight and recovery, long distance pre-programed missions, and several failsafes. Failsafes are flight modes that recover the aircraft once control is lost, low battery, or weak telemetry signals. Once sufficient data was collected and the system was proven to be reliable, the avionics team was able to proceed with integration into the newly built main aircraft.

The airframe design is composed of a wood and carbon fiber structure. Crossmembers and ribs outline the overall shape of the aircraft structure. Spars and stringers provide stiffness and strength on long stretches of the fuselage. The wing is composed of bass and balsa wood ribs spaced evenly across the main carbon spar and connected by a secondary spinner for rigidity. The skin will be made from a heat shrink thermoplastic wrap to form the aircraft's overall shape.

The Avian 4260-800Kv Outrunner Brushless Motor was selected for its balance of power, reliability, and efficiency, making it ideal for the RC plane's performance needs. With a maximum wattage of 810W and excellent cooling, it ensures smooth acceleration and torque for demanding flight phases, including carrying a payload. The motor's lightweight design, paired with precision balancing and low maintenance, provides long-lasting durability.

When the final aircraft design was completed, the team began manufacturing its components. A laser cutter was utilized to produce the majority of parts in-house, allowing for greater control over fabrication. As manufacturing progressed, assembly of the aircraft commenced in parallel, enabling the team to identify and implement small refinements to optimize performance. After constructing the aircraft's structure, the team has been integrating the proven avionics to ensure functionality and reliability.

4.2 Project Results

Despite the shift in project scope, the team has worked diligently to recover lost time and produce a flyable aircraft. At this stage, the aircraft is nearing its first flight, with final tasks such as wiring and shrink-wrapping still in progress. This process has provided valuable experience in adaptive engineering decision-making, iterative design, and preparing the aircraft for real-world testing and validation.

4.2.1 Airframe and Structure

Originally, the design of the aircraft was heavily influenced by the captive carry configuration of the X-1 glider. However, after the team decided to forgo the glider due to the inability to compete in the competition, the aircraft's design was no longer constrained by the integration of a glider attached to the belly of the aircraft. This allowed for greater flexibility in optimizing the fuselage for weight reduction, structural integrity, and aerodynamic performance as well as the landing gear.

Given that weight is a critical factor in maximizing flight efficiency, the airframe was constructed primarily from lightweight balsa wood. To reinforce areas subjected to higher loads, such as the fuselage near the wing root and landing gear mounts, basswood was strategically incorporated to increase stiffness. The entire structure will then be covered in Monokote, a lightweight yet durable heat-shrink film that enhances aerodynamics while providing a smooth, low-drag surface finish.

During the wing's assembly, the team identified an unintended geometric twist at the wingtips, which resulted in a negative angle of attack. This presented a significant challenge, as a negative angle of attack can hinder lift generation during takeoff, potentially compromising the aircraft's ability to achieve flight. To counteract this issue, the team quickly adapted by modifying the landing gear configuration from a tricycle setup to a taildragger orientation. By lowering the rear of the aircraft, the modified stance effectively increased the wing's angle of attack on the ground, ensuring a more favorable lift condition during takeoff.

This rapid problem-solving and design adaptation exemplifies the team's ability to assess and respond to manufacturing challenges in real time, ensuring the final design maintains optimal performance. An up-to-date image of the aircraft is shown below in **Figure 10**.

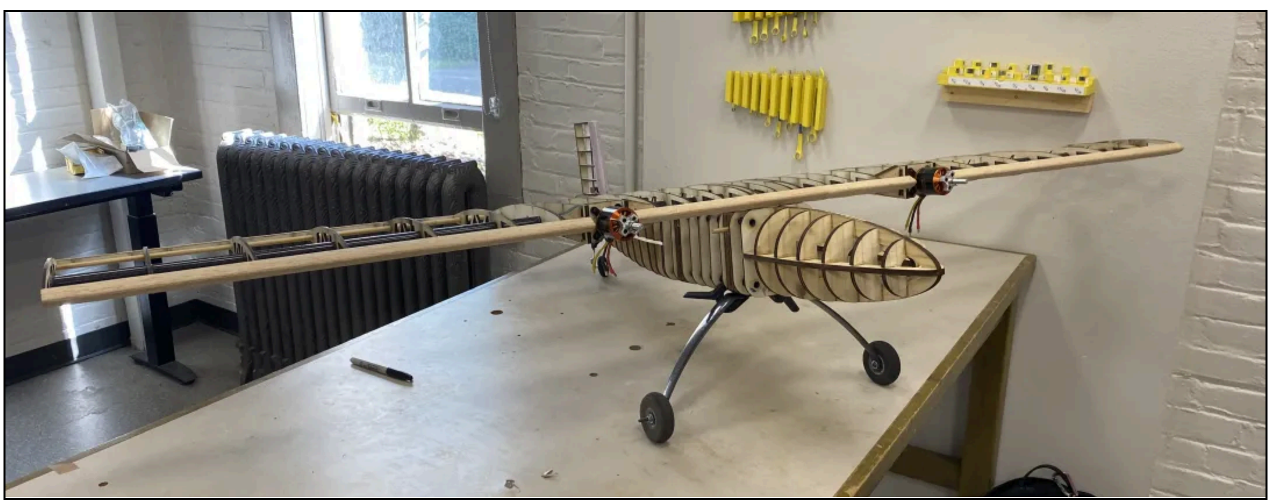


Figure 10: Picture of the aircraft assembled, highlighting the fuselage and landing gear design

4.2.2 Propulsion and Autonomy

The propulsion system was validated through RC benchmark testing, an RC software, confirming the Avian 4260-800Kv outrunner brushless motor met performance requirements for power, efficiency, and reliability. The motor provided sufficient thrust for flight, including payload carrying, while maintaining consistent performance during testing.

Figure 11: Motor Testing

The ArduPilot autopilot system was successfully tested on a retrofitted off-the-shelf aircraft, demonstrating stabilized flight, autonomous navigation and landing, and recovery in case of failures such as low battery or weak telemetry signals. With successful configuration tests completed, the system was partially integrated into the main aircraft, and flight testing will soon begin to validate its performance.

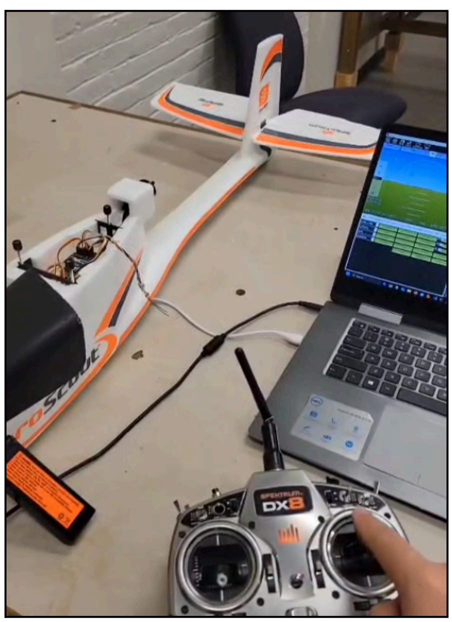


Figure 12: ArduPilot on retrofitted plane

5 LOOKING FORWARD

DBF has gone a long way with manufacturing and producing a flying plane, and in the upcoming weeks from the report date, the team will have the opportunity to test its flight worthiness. This test flight will be the maiden flight for the aircraft and will occur at the Brian Unwin Field. This test will undergo a pre-flight checklist to ensure all flight surfaces, avionics, propulsion, and navigation are working properly. Multiple flights will occur, assuming a successful maiden flight, in which autonomous capabilities will be implemented to the plane, as mentioned before. These secondary flights will use the autonomous capabilities through a flight course of waypoints to test the stability and navigational accuracy of the autopilot. If all successful, the team may opt in to attempting autonomous landing.

To future Oregon State University DBF teams, many observations were made in the learning process of this complex project that the team deems valuable to improve the project, not just in this year's design and manufacturing process, but for all future DBF related projects. Below are a few items worth noting to these future teams for the best results.

This year's DBF team faced numerous obstacles and challenges, and one obstacle was time. Over the two academic terms, the team realized just how quick time flew by and realized that every single day and meeting matters. While in the present, it may seem as a minor setback to not have completed much in one week or to be okay with getting a week behind schedule, however, days turn to weeks and turn to months and before the team knew it, it was the end of the two terms.

A few ways to combat this issue of staying on schedule and being proactive with time spent on this project include the phases of design and manufacturing. It can be easy to stay in a design loop of wanting everything to be perfect, or design choices constantly wanting to be updated, but it is from experience that the team agrees that it will never happen. Across the engineering industries, there are deadlines where projects will be submitted with much potential to be added. This is part of the real world industry where “if it works, it works” is a true statement. In regards to DBF, finding a happy medium and moving forward is the best a team can do.

The reasoning behind this is because the CADing, manufacturing, and prototyping aspect of the project is brutally painful and should be achieved as soon as possible. Learning by doing in the real world will allow for more knowledge gain and experience that the design world can ever do. So to lose as few days as possible will require the need to step away from the design phase and into the testing and prototyping phase as fast as possible.

Overall, the key takeaway is to maintain focus, work efficiently, and be willing to adjust when necessary. By balancing time management and realistic expectations, future DBF teams will be better positioned for success.

6 CONCLUSIONS

Nearing completion of this project marks a significant milestone for the team, showcasing the team's ability to apply engineering standards to develop a viable solution that meets the project's objectives. Through a structured approach, the team defined goals, explored design alternatives, conducted analyses and testing, and iteratively refined the concept to achieve an optimal end design. The final design reflects a balance between performance, safety, manufacturability, and cost-effectiveness, ensuring that the solution meets the required specifications while adhering to practical constraints. The project not only strengthened the team's technical expertise but also reinforced teamwork, problem-solving, and project management skills. Moving forward, the insights gained from this experience will serve as a foundation for further innovation and improvement in future projects and engineering endeavors.

Throughout the development of the project, the team applied fundamental design principles to create a solution that aligns with specified needs while considering key external factors. One of the most critical considerations was public safety. Ensuring the structural integrity of the design was paramount, prompting careful evaluation of material properties and load-bearing capabilities. To ensure this, the team has designed the aircraft to withstand loads much greater than those the aircraft will face. Material selection was carefully considered to enhance durability while maintaining weight and cost efficiency.

Environmental factors also played a significant role in the design process. The team prioritized sustainability by selecting materials with low environmental impact and ensuring efficient manufacturability to minimize waste. This was accomplished by manufacturing in-house to ensure environmentally friendly practices. Additionally, the strong design was optimized for longevity, contributing to reduced resource consumption over time.

From an economic perspective, cost-effectiveness was a key factor in decision-making. Working within a set budget, the team carefully evaluated purchasing decisions to maximize resource efficiency. Trade studies were conducted to compare design alternatives, considering material costs, production feasibility, and long-term maintenance requirements. This strategic approach allowed the team to develop a financially viable solution without compromising performance.

Cultural and social factors were also key considerations in the design process, particularly in ensuring accessibility and ease of use. The design incorporates user-friendly features that enhance usability and allow a broad range of individuals to engage with the assembly process. The fuselage and wing assembly were deliberately designed to be intuitive, enabling users of varying skill levels to follow the assembly process with minimal difficulty. Additionally, adherence to safety standards and regulatory compliance was prioritized to align with industry best practices, ensuring a reliable final product.

To ensure overall safety, the team implemented multiple validation steps, including prototype testing and adherence to established engineering standards. Risk assessments were conducted to identify potential failure modes, leading to the incorporation of safety factors in critical areas of the design. An example of this is adding additional support around the motor to ensure it is secured and can't come loose during flight.

In summary, the design process was guided by a comprehensive engineering approach that prioritized safety, environmental sustainability, economic feasibility, and social impact. Through meticulous consideration of these key factors, a solution was developed that not only meets stringent technical specifications but also reflects the team's commitment to broader engineering responsibilities. The result is a final design that stands as both a functional and ethical solution, one that will deliver value while positively impacting society and the environment.

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8. APPENDICES

a. Appendix A: FMEA, House of Quality

Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Potential Causes and Mechanisms of Failure	RPN	Recommended Action
1 - Wing Ribs Keep structural integrity of the wing	Crack or deformation	Loss of wing structural integrity, potential failure	High aerodynamic loads	120	Use reinforced materials, increase rib spacing
2 - Wing Spars Add strength to wing to combat bending loads	Bending or buckling	Wing collapse under load	Excessive loading, material failure	108	Use high-strength materials, add redundancy
3 - Leading Edge Cut the air to minimize drag	Surface damage or detachment	Increased drag, reduced aerodynamic efficiency	Impact, poor attachment	105	Use protective coating, enhance attachment methods
4 - Trailing Spar Support the wings shape	Fracture or misalignment	Deformation of wing shape	Manufacturing defect, fatigue	108	Improve manufacturing QC, use fatigue-resistant materials
5 - CS Hinge Material	Hinge failure	Loss of control surface functionality	Wear and tear, material fatigue	180	Use wear-resistant materials, perform regular maintenance
6 - Wing Panel Outer section of the wing enclosing the ribs and spars	Cracks or delamination	Compromised aerodynamic performance	Material fatigue, stress	84	Use composite materials, improve bonding methods
7 - F405 Mini Wing Flight controller	Software or hardware failure	Loss of flight control functionality	Software bugs, electronic failure	60	Update firmware regularly, add redundant systems
8 - Wing Control Surfaces Control the aircraft	Bending or Buckling	Loss of flight control	Excessive loading, material failure	81	Use high-strength materials, add redundancy
9 - Landing Gear Base for the plane in contact with the ground from the wheels	Buckling or detachment	Aircraft instability during landing or takeoff	Overload during landing, material fatigue	108	Use high-strength materials, ensure proper attachment
10 - Wheels Connect to landing gear and make contact with ground	Fracture or deformation	Loss of mobility on the ground	Impact during landing, wear and tear	160	Use durable materials, perform regular maintenance

DBF HOUSE OF QUALITY
ENGR 415

Project: DBF
Date: 12/07/2024
Team Members: Miguel, Ahmed, Adael, Jack, RJ, Henry

ES #	Engineering Specifications (auto-entered)	1	2	3	4	5	6	7	8
1	Width of Wings(ft)								
2	Weight of Mothership (lbs)	^							
3	Pitch and Roll and Yaw within ±5°	v	v						
4	Weight of Payloads (oz)	+	-	^					
5	Cost ($)	+	-	+	+				
6	Ease of Assembly and Repair (sec)	+	+	+		+			
7	Accurate Waypoints (within 1 meter)	-	+		^	+	-		
8	Thrust (N)	+	^	-	+	+	-	v	
9	Lift (N)	^	^	+	^	+	+	-	^

Engineering Specifications (ES)

#	Customer Requirements (CR)	Customer Weights		Width of Wings(ft)	Weight of Mothership (lbs)	Weight of Payloads (oz)	Pitch and Roll and Yaw within ±5°	Cost ($)	Ease of Assembly and Repair (sec)	Accurate Waypoints (within 1 meter)	Thrust (N)	Lift (N)			
		Direction		≥	≤	T	≤	≤	≤	≤	≥	T			
1	Max 6 foot Wingspan	5		9	3			3	1		9	9			
2	Max 55lbs for Mothership	2		3	9	3		1	1		9	9			
3	Fuel Tanks	4		1	3	9		1			3	3			
4	Flight Course	2					9			3					
5	Stay Within Budget	4		1	3	1		9			1	1			
6	Easy to assemble and Repair	3		1				1	9						
7	Plane must fly autonomously	5		1			3	1		9					
8	Stable flight	5		9	9	1	1			3	3	3			
	ES Ranking Calculations	Raw score		112	102	51	38	65	34	66	94	94			
		Scaled		1.00	0.91	0.46	0.34	0.58	0.30	0.59	0.84	0.84			
		Relative Weight		17%	16%	8%	6%	10%	5%	10%	14%	14%			
		Rank		1	2	7	8	6	9	5	3	3			

b. Appendix B: Preliminary and Updated Budget

CATEGORY	ITEM	COST (USD)
Structures	Wood & Metals	$1,250.00
	Composites	$1,500.00
	Monokote	$350.00
	Payload Materials	$250.00
	Hardware	$500.00
Sub-Total		$3,850.00
Electronics	Motors/Servos	$750.00
	Wiring	$100.00
	Transmitter/Reciever	$350.00
	Batteries	$500.00
	ESC	$300.00
Sub-Total		$2,000.00
Manufacturing and Testing	Tools	$150.00
	Trainer Aircraft	$250.00
	Test Cage	$100.00
	Test Fixtures	$150.00
Sub-Total		$650.00
Travel	Airline Tickets	$3,500.00
	Rental Vehicle	$2,000.00
	Aircraft Shipping	$600.00
	Lodging	$2,500.00
	Food	$3,500.00
Sub-Total		$12,100.00
Total Cost		$18,600.00

CATEGORY	ITEM	COST (USD)
Structures	Wood & Metals	$1,250.00
	Composites	$1,500.00
	Monokote	$350.00
	Payload Materials	$250.00
	Hardware	$500.00
Sub-Total		$3,850.00
Electronics	Motors/Servos	$750.00
	Wiring	$100.00
	Transmitter/Reciever	$900.00
	Batteries	$500.00
	ESC	$400.00
Sub-Total		$2,650.00
Manufacturing and Testing	Tools	$150.00
	Trainer Aircraft	$400.00
	Test Cage	$100.00
	Prop Test Stand	$700.00
	Test Fixtures	$150.00
Sub-Total		$1,500.00
Total Cost		$8,000.00