Wolf Airlines: Urban Air Mobility Vehicle for Passenger and Medical Transportation

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The 2023-2024 AIAA Design, Build, Fly competition solicits an Urban Air Mobility aircraft that can perform a medical transport flight and carry passengers in separate configurations. Aiming to reduce the response times for medical aircrafts, along with improving the current mobility for those living in urban environments, team Wolf Airlines generated the Wolfline. The purpose of this project is to design and manufacture a fixed-wing, STOL Urban Air Mobility Vehicle that can be utilized for both medical transport and passenger transport missions. The team's aircraft, dubbed the Wolfline, will be constructed to have a highly versatile and interchangeable cabin, as it must carry 2 emergency medical technicians (EMTs), a gurney with a patient, and a medical cabinet for the medical transport mission as well as carry a minimum of 8 passengers for the passenger transport mission. The Wolfline will always have a flight crew of two members, each seated forward of the cabin bulkhead. Finally, the plane must be able to fit in a parking spot that is 2.5 feet in width, potentially requiring the implementation of rotating wings. The finished Wolfline shall complete all these missions while being within the design constraints of the Design, Build, Fly competition. The design solution developed to meet the requirements outlined by the 2024 AIAA DBF competition is a high wing, T-tail aircraft with a single engine in a tractor configuration. The wing is rectangular and has a span of 55 inches and a chord length of 10 inches. There is no taper, sweep, or twist on the wing. The aspect ratio of the main wing is 5.5 allowing for a high lift wing while limiting drag seen by lower aspect wings. In order to make the Wolfline compatible with the short takeoff and landing requirements set by AIAA DBF, flaps and vortex generators will be used on the main wing to help generate lift and keep airflow attached at higher angles of attack. Theoretical and experimental analysis, conducted through simulations and evaluations, will occur prior to manufacturing the Wolfline.

I. Introduction

OVER the course of two academic semesters, a North Carolina State Senior Design team, Wolf Airlines, is developing a design solution of an Urban Air Mobility vehicle to fulfill the requirements of the 2024 AIAA Design, Build, Fly competition. Urban Air Mobility (UAM) is gaining popularity within the commercial air transportation industry. UAM vehicles are meant to perform high-frequency flights, transporting groups of passengers to their local/regional destinations. Big cities are investing heavily in UAM technology, reducing the dense traffic and high commute times that residents experience daily. These aircraft can also be utilized for purposes outside of commercial transportation, such as medical transport and cargo missions. For a UAM vehicle to be successful and compatible with an urban environment, it must have short take-off and landing (STOL) or vertical take-off and landing (VTOL) capability alongside high maneuverability. Since UAM aircraft mainly fly through various urban environments, parking space is limited. Therefore, when the aircraft is on the ground, it must be compact. The challenge of this competition is to push the boundaries of current technology, allowing for the innovation of UAM and STOL vehicles. Wolf Airlines will design, build, and fly an aircraft to score as many points as possible at the 2023-2024 American Institute of Aeronautics and Astronautics (AIAA) Design, Build, Fly

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Competition. The aircraft, named the Wolfline, shall carry a payload with the ability to perform delivery, medical transport, and urban flights. The aircraft, named the Wolfline, shall carry a payload consisting of crew, emergency medical technicians (EMTs), a patient on a gurney, medical supplies, and passengers while completing the given missions.

II. Project Overview

The organizational structure of the team is shown to the right. The project manager, faculty advisors, and sub-team leads are shown in the diagram. As shown, the project manager supervises and helps the sub-team leads, while the faculty advisors help manage the entire team. All the sub-team leads are integral to a successful team. Each subteam lead has a primary technical role, as shown in the figure, alongside a secondary administrative role to further develop this project.

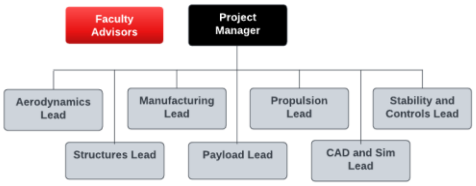

Figure 1. Organizational Structure

The purpose of this project is to design and manufacture a fixed-wing, STOL Urban Air Mobility Vehicle that can be utilized for both medical transport and passenger transport missions. This aircraft is designed according to the 2023-2024 Design, Build, Fly competition. The competition is comprised of 3 missions. The first mission requires the aircraft, designated as The Wolfline, to fly 3 laps around the course in 5 minutes with just the crew and no payload. The second mission requires The Wolfline to do the same as the first mission, except with a payload simulating a medical transport situation. The third mission dictates that The Wolfline flies as many laps as possible in a five-minute period, while also carrying as many passengers as possible. The competition judges will award points based on lap time, weight of the medical payload, and number of passengers that the aircraft can safely transport. The Wolfline will be constructed to have a highly versatile and interchangeable cabin, as it must carry two EMTs, a gurney with a patient, a medical cabinet for the medical transport mission, and carry a minimum of eight passengers for the passenger transport mission. The Wolfline will always have a flight crew of two members, each seated forward of the cabin bulkhead. Finally, the plane must be able to fit in a parking spot that is 2.5 feet in width, potentially requiring the implementation of rotating wings. The finished Wolfline should complete all these missions while being within the design constraints of the Design, Build, Fly competition [1].

Customer expectations were derived from the 2023-2024 DBF Rules, which were released on August 29, 2023. Further expectations and design requirements/restrictions were elaborated on by the 2023-2024 AIAA competitions team throughout the years as various teams prompted questions throughout the competition. Based on these customer expectations, a set of objectives were identified that needed to be accomplished which are shown in the following subsection.

The figure below demonstrates the concept of operations (CONOPS) for the three missions the Wolfline will complete. The Wolfline will be remotely controlled by the pilot and aided by the observer from the Ground Mission area. Due to wind variability, the orientation of the flight path will be adjusted according to the prevailing winds determined by the Flight Line Judge. Takeoff distance must be within 20 feet of the start/finish line. For a successful takeoff, the Wolfline shall have all ground contact points forward of the start/finish line. For all missions, upwind and downwind turns can be started once the Wolfline passes the 500-foot marker, indicated by a flag raised by the turn judge. Mission 1, the delivery flight, involves the Wolfline completing three laps in a five-minute flight window while carrying only Crew. Mission 2, the medical transport flight, involves the Wolfline completing three laps in the five-minute flight window while carrying the Crew and the Medical Payload Components. Mission 3, the urban taxi flight, involves the Wolfline completing as many laps as possible in the five-minute flight window while carrying the Crew and Passengers. Proceeding missions may not be attempted until previous missions have been successfully completed. For each mission, the Wolfline must successfully land to receive a score.

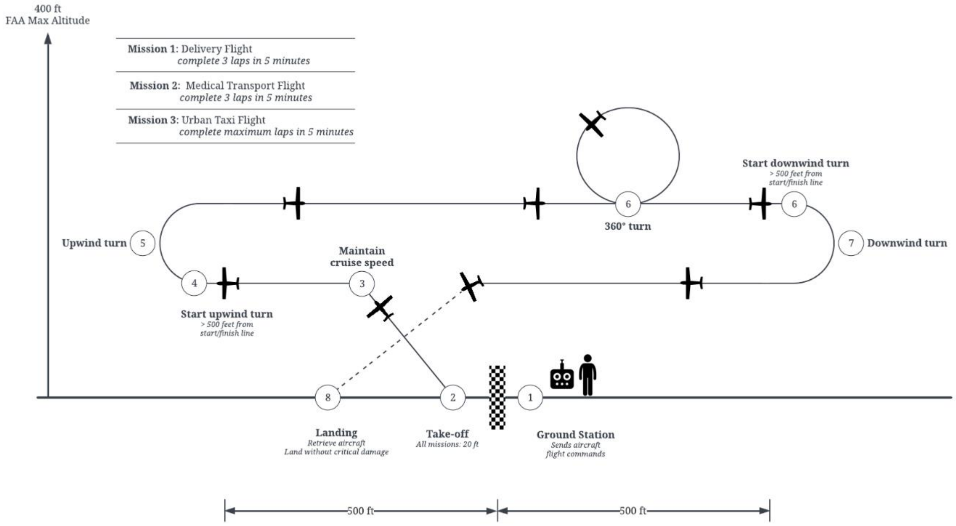

Figure 2. Concept of Operations Diagram

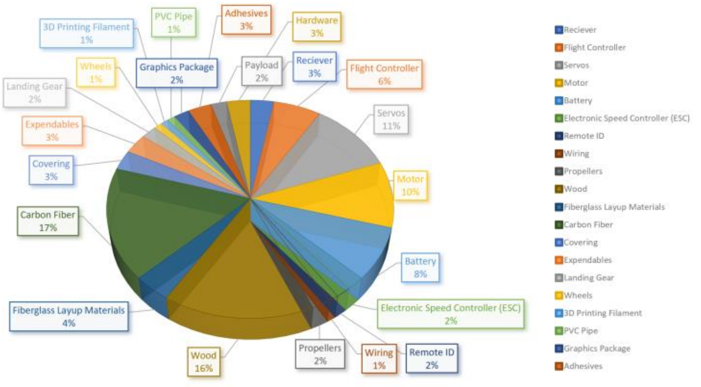

Figure 3. Development Budget Pie Chart

Following the concept of operations, a focused budget chart is created. This figure, seen to the right, allows for visualization of developmental costs associated with the actual fabrication of the aircraft, rather than the logistical costs associated with the competition. Structural materials, such as wood or carbon fiber, take up most of the budget as they comprise most of the aircraft's structure. Additionally, due to the high performance required, the motor and servos sections are sizeable.

To understand the Wolfline's components and how they are all interconnected, a functional block diagram of the system architecture was constructed. The block diagram was constructed with the requirements from AIAA in mind [1]. The Wolfline is a multipurpose aircraft with four separate subsystems. The subsystems included are power, propulsion, avionics, and flight controls. Since the aircraft will be an unmanned vehicle, communication with the ground will occur via a remote-controlled transmitter and receiver. The aircraft will be piloted by an external pilot who operates the controller from the ground. The inputs into the controller will then be transmitted to the remote control (RC) receiver onboard the aircraft. The receiver will then relay signals to the flight computer and the RC fail-safe. The flight computer then sends digital signals to the motor controller, which will be used to control the servo motors that deflect the control surfaces seen in the flight controls subsystem. The receiver will also send signals to the electronic speed controller (ESC). The ESC will control the motor rotation speed. If radio contact with the ground is lost during flight, the receiver will automatically send a signal to the RC fail-safe. The fail-safe will then send preset signals outlined in the AIAA rules to command the aircraft into a certain maneuver. Power supply onboard the aircraft will come from two different batteries. One battery will solely power the propulsion system, while the other battery will power the avionics subsystem. As per the AIAA DBF rules, the propulsion system must be powered by a battery that is solely used for the propulsion system. The battery used for the propulsion system will have different specifications than the battery for the flight computer. The batteries used in the Wolfline for the avionics and propulsion systems will also have the appropriate fuses and switches required by the AIAA DBF rules. The purpose of this functional block diagram is to lay out the high-level system architecture of the aircraft and to illustrate interactions between its subsystems.

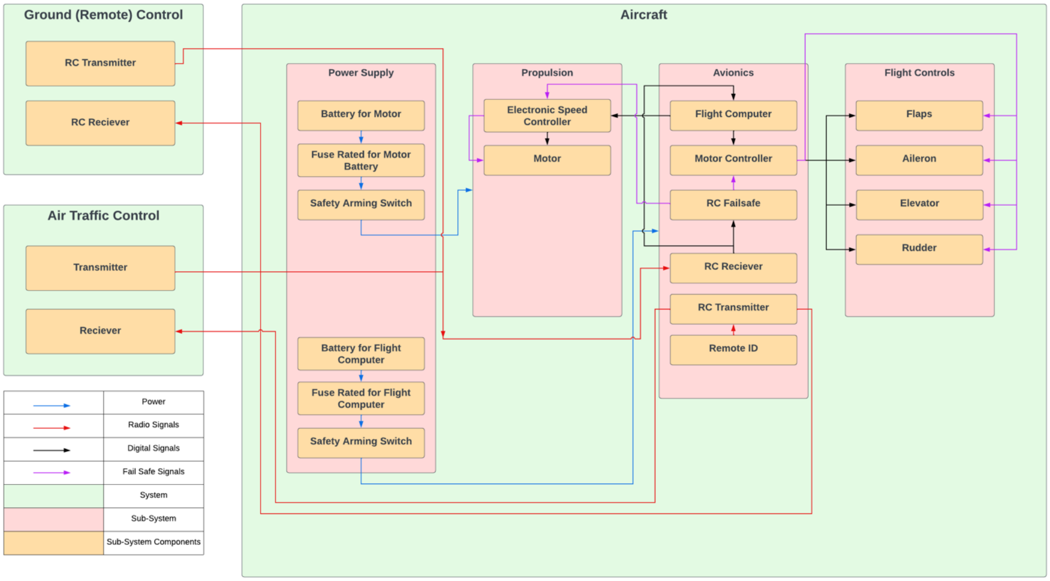

Figure 4. Functional Block Diagram for the Wolfline

III. Requirements Analysis & Design Considerations

A. Mission-Specific Requirements

The overall objectives of the project are to design and build a UAM vehicle that can carry crew, a medical crew with equipment and a patient, and passengers. In addition, the aircraft needs to be able to have different configurations for each flight for optimal payload distribution. To compete in the 2023-2024 AIAA DBF Competition, Wolf Airlines needs to complete these objectives. Different levels of completion have been assigned to each objective to what degree the objectives have been completed at. Aiming to match the requirements necessary of a top-ten team within the competition, the Wolfline must follow certain specifications: the takeoff roll with maximum payload shall be less than 20 feet, the landing should occur on a paved surface with no bouncing or damage to the airframe, the Wolfline shall complete 5 laps in 5 minutes with maximum payload, the medical supply cabinet shall constitute 40% of gross weight, the maximum passenger count shall be 20, the aircraft and payload shall be fully assembled in under four minutes. To evaluate these specifications, the scoring equations and thorough analysis will be conducted to determine the feasibility of the specifications. However, the final test to determine the feasibility will be a flight test once the plane is built.

B. Design Considerations

The design solution developed to meet the requirements outlined by the 2024 AIAA DBF competition is a high wing, T-tail aircraft with a single engine in a tractor configuration. The wing is rectangular and has a span of 55 inches and a chord length of 10 inches. There is no taper, sweep, or twist on the wing. The aspect ratio of the main wing is 5.5 allowing for a high lift wing while not creating a lot of drag seen by lower aspect wings. The max takeoff weight of the plane is estimated to be 10 pounds at takeoff. In order to make the Wolfline compatible with the short takeoff and landing requirements set by AIAA DBF, flaps will be used on the main wing to help generate lift and keep airflow attached at higher angles of attack.

Figure 5. Render of The Wolfline

In order to satisfy the requirements of the missions, the aircraft is estimated to hold 30 passengers and hold a medical cabinet weight of approximately 2.5 pounds. To ensure that the aircraft fits within the designated parking spot width of 2.5 feet, the wings of the aircraft will rotate along the aircraft's vertical or "z" axis. The wing will rotate using the wing to fuselage mount which is explained in greater detail further in the document. These designs were selected with the need to create a functional RC aircraft that can take off within the designated 20-foot runway and maintain stable flight throughout all mission profiles.

IV. Design Solution

A. General Solution Features

Below is the baseline design of the Wolfline based on trade studies following the mission-specific requirements and design considerations. The detailed designs based on each subsystem are explained in the following sections.

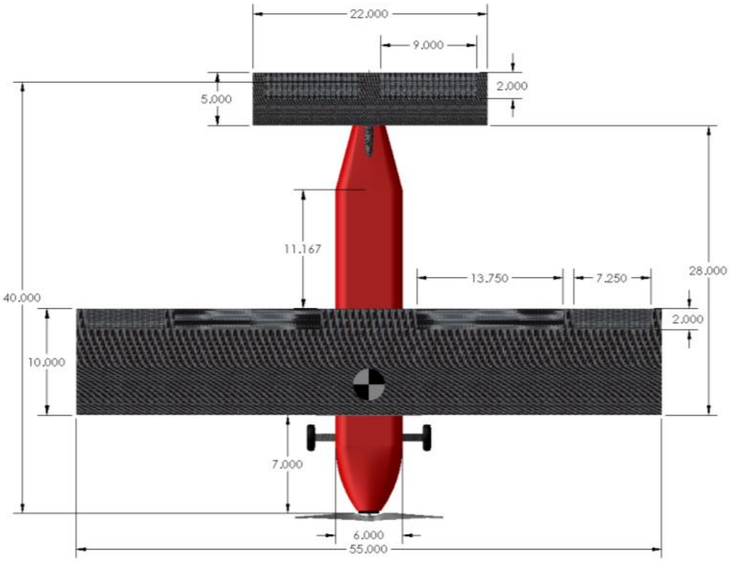

Figure 6. Top View of The Wolfline with Dimensions in Inches

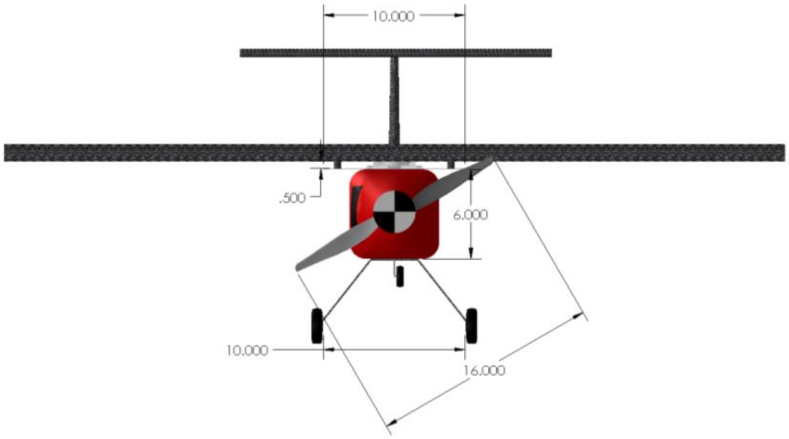

Figure 7. Front View of The Wolfline with Dimensions in Inches

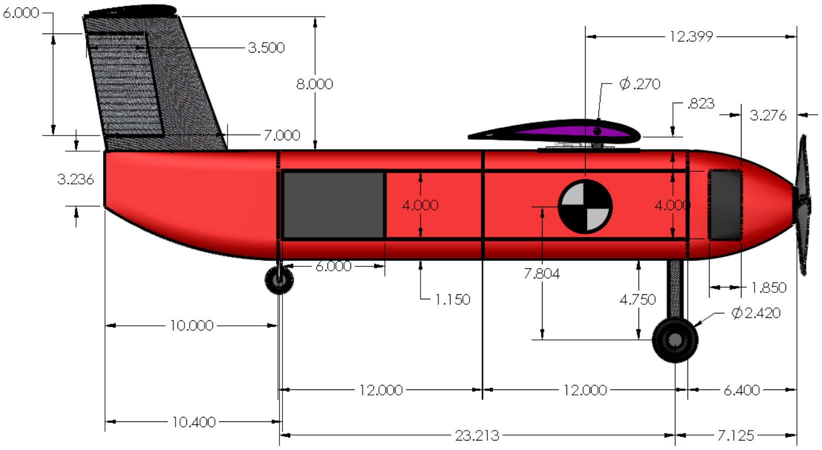

Figure 8. Side View of The Wolfline with Dimensions in Inches

B. Performance Parameters

Table 1. Geometry and Performance Parameters

Parameters	Size
Aspect Ratio	5.5
Wingspan	55 in
Wing Area	550 in^2
Nose to Tail Length	40 in
Wing Taper Ratio	1
Horizontal Tail Area	110 in^2
Horizontal Tail Volume Ratio	0.6
Horizontal Tail Taper Ratio	1
Vertical Tail Area	50 in^2
Vertical Tail Volume Ratio	0.05
Vertical Tail Sweep	20 deg
Vertical Tail Taper Ratio	0.78
Static Thrust to Weight Ratio	1.88
Cruise Speed	40 mph
Maximum L/D (at 5° AoA)	12.41

Some key dimensions that are shown in the figure are that the aspect ratio for the main wings is 5.5, due to the wingspan being 55 inches and the chord being 10 inches. The root leading edge of the vertical tail is approximately 13 inches from the trailing edge of the wing, and the leading edge of the horizontal tail is approximately 28 inches from the leading edge of the wing. The horizontal tail span is 22 inches, and the chord is 5 inches. Furthermore, the landing gear is set up so that the aircraft rests at an angle of attack of 10 degrees when all wheels contact the ground. The center of gravity (CG) is 7.804 inches from the center of the landing gear, which means that the center of gravity is approximately 10 inches from the ground in the shown configuration. The width of the landing gear support system is 10 inches and the propeller is 16 inches in diameter.

C. Internal Layout

The figures below detail the Wolfline's internal layout, including a passenger configuration render. Based on the finalized fuselage design, it is estimated that the Wolfline will be able to carry a total of roughly 12-18 passengers. This is with the design solution where each passenger payload cartridge will house three passengers. The passenger cartridge size is not expected to change due to the size restrictions provided by the passengers themselves as well as the overall fuselage dimensions. To optimize the total number of passengers within the fuselage, the payload restraint system sizing will be minimized while still maintaining its structural integrity during flight. The passenger capacity is currently favorbale, aligning with Wolf Airlines goals and the regulations provided by the 2023-2024 AIAA DBF competition.

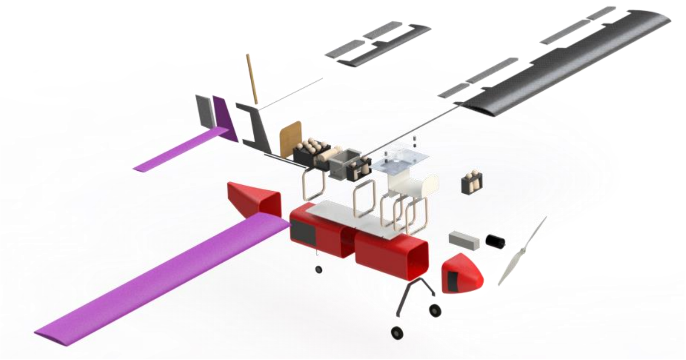

Figure 9. Exploded View of The Wolfline

Figure 10. Passenger Configuration Side View

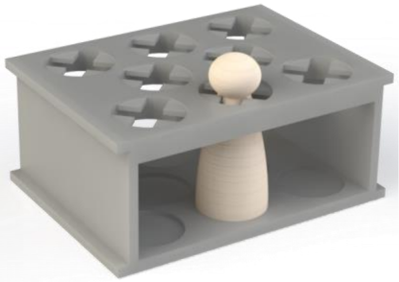

Figure 11. Payload Restraint System

The results from various trade studies conclude that the optimal payload restraint system is the multi-row design. This design is chosen as the baseline design to accommodate the number of passengers chosen from the scoring analysis in relation to the mission profiles. This restraint system encompasses a simple design that allows multiple passengers to be quickly installed and removed for each of the required sections. Additionally, the selected design is easy to manufacture and optimizes space inside the fuselage to allocate additional space for other components.

D. Wing Fold Design Solution

The Wing to Body mounting system is shown in the figure to the right, including the rotation system pictured in red. The parts on the bottom will be mounted to the top of the fuselage, which include the aluminum 6061 reinforcement plate, 2 rubber spacers, and the male rotation hinge. The reinforcement plate is engineered to transfer the loads from the wing to fuselage by spreading the loads along an area so that they are not all concentrated at one point. The left and right sides of the aluminum plate will hand off the side of the fuselage by about 1 inch. This will allow a bolt to be inserted through the reinforcement plate and into the wing to secure the aircraft in its flight configuration.

The three parts floating in the air on the figure above will be manufactured into the wing. The two floating cylinders are the aluminum bolt sleeves, which are threaded at the bottom and are secured in place by having the wing spar run through the top. The top rotation hinge will also be manufactured into the wing, with the square part cured underneath the carbon fiber, leaving only the circular rotator exposed.

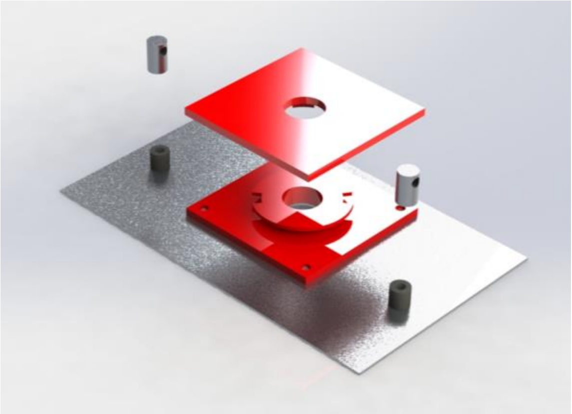

Figure 12. Wing Rotation Mechanism

On the base rotation hinge, two cutouts can be seen. These cutouts are intended for easy removal of the wing strictly for maintenance purposes, as they allow the operator to rotate the wing counterclockwise and remove it once the tabs on the top rotation mount meet the slots. When the operator wants to put the aircraft in the parking configuration, they will remove the bolts connecting the plate to the wing and rotate the wing clockwise.

V. Subsystem Analyses

A. Aerodynamic Analysis

1. Airfoil Selection and Wing Design

A preliminary analysis was done in XFLR5 and was further supported by empirical data on the stalling characteristics of the NACA 4412 and NACA 0012 airfoils. The following analysis was done at Reynolds Numbers between 500,000 and 1,000,000 since this is the expected range of Reynolds Numbers for the aircraft at cruise speed. Sea level values were used for density and dynamic viscosity of air.

The following graphs show the lift coefficient versus angle of attack (alpha) for the NACA 0012 and 4412 airfoils. The leftmost graph shows that the stall angle for the NACA 0012 airfoil is roughly 15 degrees. The Wolfline has an incidence angle on the tail that causes the whole surface to be deflected at an angle of -2 degrees. When the aircraft is at an angle of attack of 15 degrees, the tail is realizing an actual angle of attack of 13 degrees.

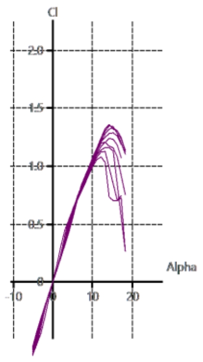

Figure 13. Lift Coefficients vs. Alpha for NACA 0012

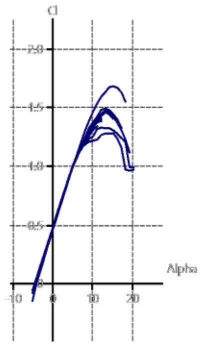

Figure 14. Lift Coefficient vs. Alpha for NACA 4412

The rightmost graph shows the lift coefficients versus alpha for the NACA 4412 airfoil. The graph follows a similar pattern, with a slightly higher $C_{L,max}$ than the NACA 0012. The stall region of the NACA 4412 airfoil starts at around an alpha of 15 degrees. Since the tail will always be at an alpha that is 2 degrees behind the alpha of the overall aircraft, it can be concluded that the aircraft will not enter a deep stall under normal flight conditions. The incidence angle of the tail helps to generate negative lift to keep the nose pitch up but also aids in making sure the alpha of the tail is not more than that of the aircraft.

Based on conclusive aerodynamic analysis, it is concluded that a NACA 4412 airfoil should be used for the wing. The 4412 airfoil is positively cambered, allowing for higher lift at lower speeds which will aid in short take-off and landings. Furthermore, the 4412 has a slightly curved bottom which makes it a simple airfoil to manufacture. Additionally, semi-symmetrical airfoils such as the 4412 are maneuverable and have favorable lift to drag ratios. This maneuverability in the airfoil helps to combat the sluggish tendencies that are sometimes experienced by a high-wing design. Furthermore, previous aerodynamic analysis pertaining to the wing selection determined that an untapered, flat wing should be implemented for wing geometry. Not only is this the simplest model to manufacture, the untapered wing will allow desired aerodynamic characteristics while reducing complexity. The local lift coefficient at the wing tips will not reach a maximum that tapered wing designs generally experience, reducing the risk of tip stalls during ordinary flight regimes.

2. *Aerodynamics of the Critical Phases of Flight*

In order to properly understand the Wolfline's expected aerodynamic performance characteristics during the missions outlined by the 2023-2024 DBF Competition, various simulations have to be conducted for the critical phases of flight. These critical phases include cruising and takeoff conditions, where cruising is defined by the trim angle of attack of two-degrees and takeoff is defined by 10-degrees angle of attack. A mesh of the aircraft is created in OpenVSP to evaluate pressure coefficients relations, vorticy flow simulations, control surface deflections, and further stability characteristics of the Wolfline. Analysis was conducted to confirm vorticity distributions found through ANSYS and FlightStream. In ANSYS, the generalized k-ω (GEKO) turbulence model was utilized to analyze the flow, and the GEKO model was set up using the default Fluent settings. Trailing edge vortices are formed due to the differential of pressures interacting with each other at the wingtips. This interaction generates the trailing vortices that are shown in the images. The figures below demonstrate the cruising and takeoff trailing vorticies for the Wolfline, with crusing corresponding to trim angle of attack and takeoff corresponding to 10-degrees angle of attack.

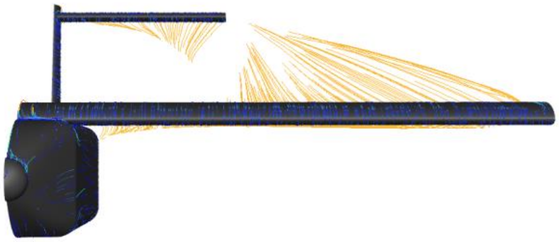

Figure 15. Vortices at trim angle of attack, front view ANSYS

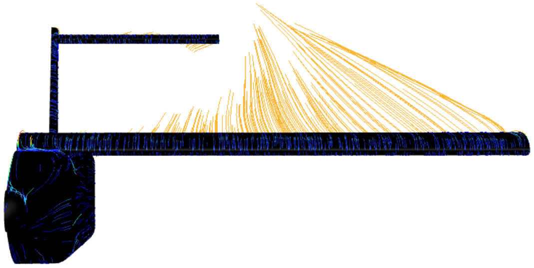

Figure 16. Vortices at 10-degrees angle of attack, front view ANSYS

Note the flow across the main wing planform does not intersect the flow from the horizontal T-tail at the trim or takeoff angle of attack. Trailing edge vortices flow as expected in both simulations and will not cause a major issue in vortex drag at this flight condition. As expected, these wingtip vortices are higher in magnitude for the takeoff angle of attack when compared to the trim angle of attack. Due to the greater pressure distributions inflicted on the wing surfaces during the critical phases of flight, these results are understandable. Note that at this 10-degree angle of attack, the flow across the main wing planform does not majorly interfere with the flow across the horizontal T-tail planform.

B. Stability & Control

In order for the Wolfline to successfully compete in the DBF competition, it must exhibit longitudinal and lateral stability at all points regardless of the mission or payload. The stability of the Wolfline is estimated using the Athena Vortex Lattice (AVL) software. The design that is modeled in AVL is a high wing aircraft, with a T-tail design. The moment arm between the leading edge of the wing and the leading edge of the horizontal tail is 28 inches. The CG is placed at 11, 12, and 13 inches from the nose of the aircraft in AVL to get an operating envelope of CG locations. The chosen airfoils for this stability analysis are the NACA 4412 for the main wing and NACA 0012 for the vertical and horizontal tails. The stability derivatives found are the values taken at zero-lift of the aircraft. The aircraft is expected to cruise in the range of 35-55 miles per hour, so this analysis is done at a speed of 40 miles per hour.

Table 2: Stability Derivatives from AVL

Center of Gravity Location (in)	$C_{m\alpha}$	$C_{l\beta}$	$C_{n\beta}$	X_{NP} **(in)**	α_{Trim} **(deg)**
11	-1.360152	-0.018806	0.082944	13.97	0.4714
12	-0.899035	-0.018622	0.079703	13.97	2.0372
13	-0.437917	-0.018439	0.076463	13.97	5.346

It should be noted that as the center of gravity shifts backwards the aircraft will exhibit less pitch stability, which is shown by the increasing of $C_{m\alpha}$ as CG location moves back. The static margin of the aircraft is higher when the CG of the aircraft is farther towards the leading edge of the wing, or more forward of the neutral point. In the above table, a CG location of 11 corresponds to a static margin of 30%, a CG location of 12 inches corresponds to a static margin of 20%, and a CG location of 13 inches, corresponds to a static margin of 10%. The neutral point, estimated by AVL, is 12 inches aft from the tip of the nose. This means that the neutral point of the aircraft sits 5 inches behind the leading edge of the wing. The neutral point stays in the same location for all of the CG locations as it is a property of the geometry of the aircraft, which is not changing. The above table shows a sensitivity analysis of the stability derivatives with respect to CG movement. Please note that for the Wolfline, a static margin of 20% was chosen and the center of gravity will be 12 inches back from the nose of the aircraft, or 5 inches back from the leading edge of the wing.

The Wolfline has shown that it has multiple configurations in which it can be stable. However, several stability characteristics of the Wolfline have now been fully defined and a center of gravity point, static margin, and neutral point location have all been determined. Additionally, the Wolfline also utilizes flaps, ailerons, elevators, and rudders to combat any disturbances that may arise during flight and to help bring the aircraft to a trimmed state. The control surfaces have the following areas, and their max deflections are listed below.

Table 3. Control Surface Dimensions

Control Surface	**Area per Half Span of Wing** in^2	**Max Deflection (TEU) (degrees)**	**Max Deflection (TED) (degrees)**
Flaps	27.5 (13.75 in x 2 in)	N/A	20
Ailerons	14.5 (7.25 in x 2 in)	20	20
Elevators	18 (9 in x 2 in)	25	22
Rudder	17.60 (not half span dimension)	20 (TE Right and Left)	

Table 4. General Stability Solution

Parameter	**Value**
Center of Gravity Location	12 inches aft of nose
Neutral Point Location	14 inches aft of nose
Static Margin	20%
$C_{m\alpha}$	-0.899035
$C_{l\beta}$	-0.018622
$C_{n\beta}$	0.079703
Zero Lift Alpha Trim	2.0372 degrees

C. Structures Analysis

1. *Fuselage Structure*

The fuselage is composed of two major structural subsystems: the shell and the ribs. The shell is a one-ply fiberglass-epoxy composite utilizing a biaxial and heavier weave. The shell is of a monocoque design and is structurally rigid. The shell will be split into four sections: a nose section, one middle section containing the payloads, and a rear section. The primary purpose of the shell is to provide resistance to bending and to provide a smooth aerodynamic surface that is self-supported.

The middle fuselage section will have a rectangular cross-section with rounded edges, with the section being manufactured in one piece. The nose and rear sections will be constructed in a similar manner, but are tapered at the ends. The nose will be supported by internal supports to secure the motor, battery and pilots. The main fuselage section will be supported with an internal rib and longeron structure, and the tail section will have a wooden block to attack the empennage to.

The ribs' primary purpose is to bear the concentrated shear loads at structurally critical locations. The ribs have a much greater shear resistance than the shell, which will prevent the shell from buckling due to stress concentrations. The ribs will be strategically placed in the fuselage at locations with the highest shearing. This includes the wing box, medical payload, main gear, tail gear and vertical tail attachment point.

The door cutout will be placed in the side of the aft middle section. The corners will be rounded to prevent stress concentration, and a reinforcing frame will be placed around its perimeter to ensure shear failure does not occur.

2. *Wing Structure*

The wing is composed of an extruded polystyrene foam (XPS foam) core and a carbon fiber-epoxy skin. The skin layup will consist of two biaxial layers, both at 0 degrees orientation.

The carbon fiber skin will bear almost all of the bending loads. The foam core prevents the skin from deforming under shear loads, as well as providing continuity throughout the wing. The lift force on the wing will be transferred to the fuselage through two vertical bolts, one on each side. Each bolt will screw into a threaded insert in the wing. The insert is connected to a thin carbon fiber spar, which is embedded in the foam. The spar extends slightly past the edge of the fuselage; its primary purpose is to distribute the load from the foam to the bolts evenly. The spar will also help resist some of the shear force at the root of the wing.

D. Power & Performance

Using the website eCalc, the configuration for the components of the propulsion system (which includes the motor, battery, ESC, and propeller) were chosen. The initial assumptions include that the aircraft was a monoplane with one motor, has a gross weight of 12 pounds, a wingspan of 55 inches, and a wing area of 550 sq in. Furthermore, the airplane has a cruise speed of 40 mph (or 18 m/s) and has at least 9000 g of thrust. This is so the thrust to weight ratio is around 2:1 to ensure airplane can accelerate quickly to take off within 20 ft. This was also done under the assumption that the aircraft will fly at less than 100% throttle at cruise and landing to cruise at a thrust to weight ratio closer to 0.8:1 for increased maneuverability and endurance. The mixed flight time was set to 6 minutes to ensure that the plane can fly for the 5 minutes required with a bit more as a buffer. From the analysis, a 8S 29.6 Volt 3300 mAh LiPo Battery, 100 Amp ESC, 16x10 in. APC propeller, and a HET (Typhoon) 800-73-400 motor was chosen. With this setup, the thrust to weight ratio is 1.88:1 at full throttle and 0.71:1 at 53% throttle.

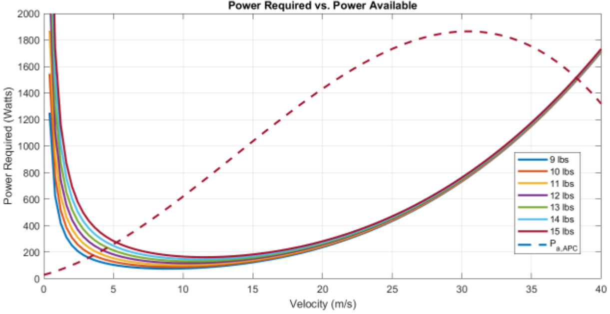

Figure 17. Power Required vs. Power Available

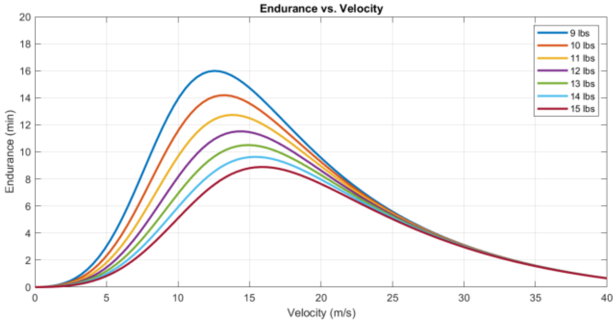

Figure 18. Endurance vs Velocity

The figure on the left above show the relationship between power required and freestream velocity across a range of aircraft masses. The dashed line on the graph represents the available power for the aircraft. By depicting power required on one axis and power available on the other, this graph provides a visual insight into whether the available energy resources meet the needs of the given system. The Wolfline is expected to weigh a maximum of 12 lbs. and fly at a velocity of 18 m/s. The analysis done at these conditions show that there is excess power available. A surplus of power is advantageous for efficiency and ensuring consistent power for the motor. Additionally, high excess power is beneficial as the Wolfline will need a high thrust to weight ratio to take off within 20 feet. The figure on the right above displays the endurance of the aircraft at various weights and velocities. The figures show that the propulsion system operates well at the expected flight conditions of 12 lbs. and a velocity of 18 m/s. Furthermore, these figures demonstrate that the system is designed optimally as the aircraft is near the maximum possible rate of climb for the expected conditions.

VI. Conclusion

This report discusses the design process that is crucial to the overall performance of a successful fixed wing UAM aircraft to compete in the 2024 AIAA Design, Build, Fly competition. The evaluation and selection of various components complete the preliminary design portion of the overall project. Following preliminary design, further testing and analysis is conducted, including airfoil selection, wing design and positioning, tail design and configuration, and propulsion system design. Covered throughout this report is a detailed analysis of the overall design processes that is to be implemented in Wolf Airlines' manufacturing of the Wolfline for the 2024 AIAA Design, Build, Fly competition.

Multiple design options are considered for each component, with detailed trade studies and simulations performed to fully evaluate each option. Each trade study revealed an optimal design, which is further supported with feasibility analysis. The prevailing design is a single engine monoplane with a tractor engine configuration, high rectangular wing, T-tail, and tricycle landing gear capable of being configured to transport 20 passengers or medical patients and supplies.

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