SAE Aero Design West 2024
Micro Class Final Report

University of West Florida, Pensacola
UWF Argonautics
Team 324

Faculty Advisor: Dr. Brad Regez

Team Members: Alyssia Bryson, D'Andre Walden, Ashley Creighton, Kamran Bineshtarigh, Brett Brustad, Aza Boykin, Joseph Pusateri, Camden Chambers, Hayden Pursell, Kassandra Gartman, Caiden Patton, Hunter Wagner, Kaitlyn Williams, Joseph Pusateri, Joel Gonzalez, Connor Yourist, William Emiro, Liberty Mclean

Argonautics Team

UNIVERSITY of WEST FLORIDA

Certification of Qualification

Team Name: UWF Argonautics   Team Number: 324

School: University of West Florida

Faculty Advisor: Brad Regez

Faculty Advisor's Email: bregez@uwf.edu

Statement of Compliance

As faculty Adviser:

BR (Initial) I certify that the registered team members are enrolled in collegiate courses.

BR (Initial) I certify that this team has designed and constructed the radio-controlled aircraft in the past nine (9) months with the intention to use this aircraft in the **2024** SAE Aero Design competition, without direct assistance from professional engineers, R/C model experts, and/or related professionals.

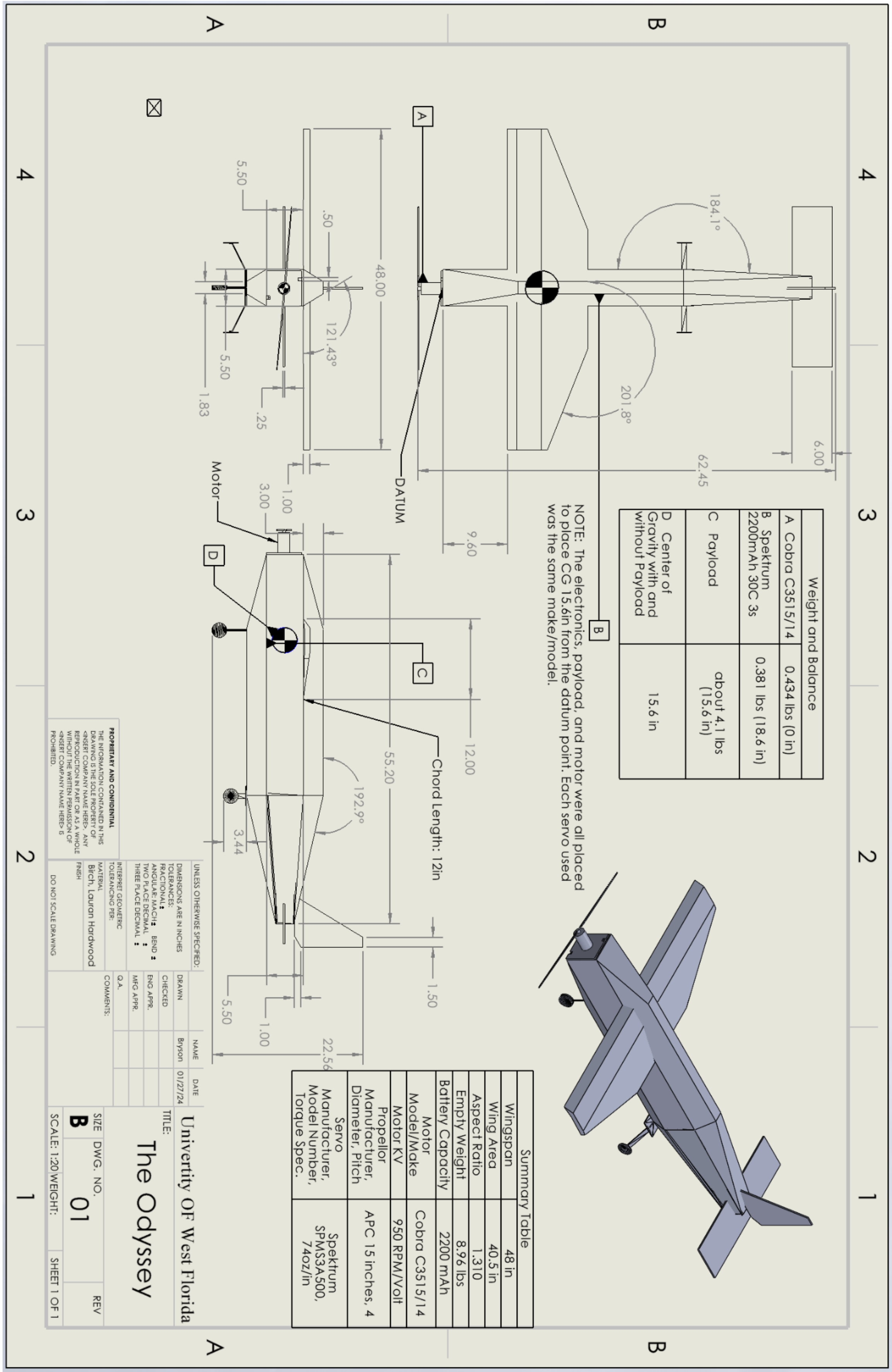
BR (Initial) I certify that this year's Design Report has original content written by members of this year's team.

BR (Initial) I certify that all reused content have been properly referenced and is in compliance with the University's plagiarism and reuse policies.

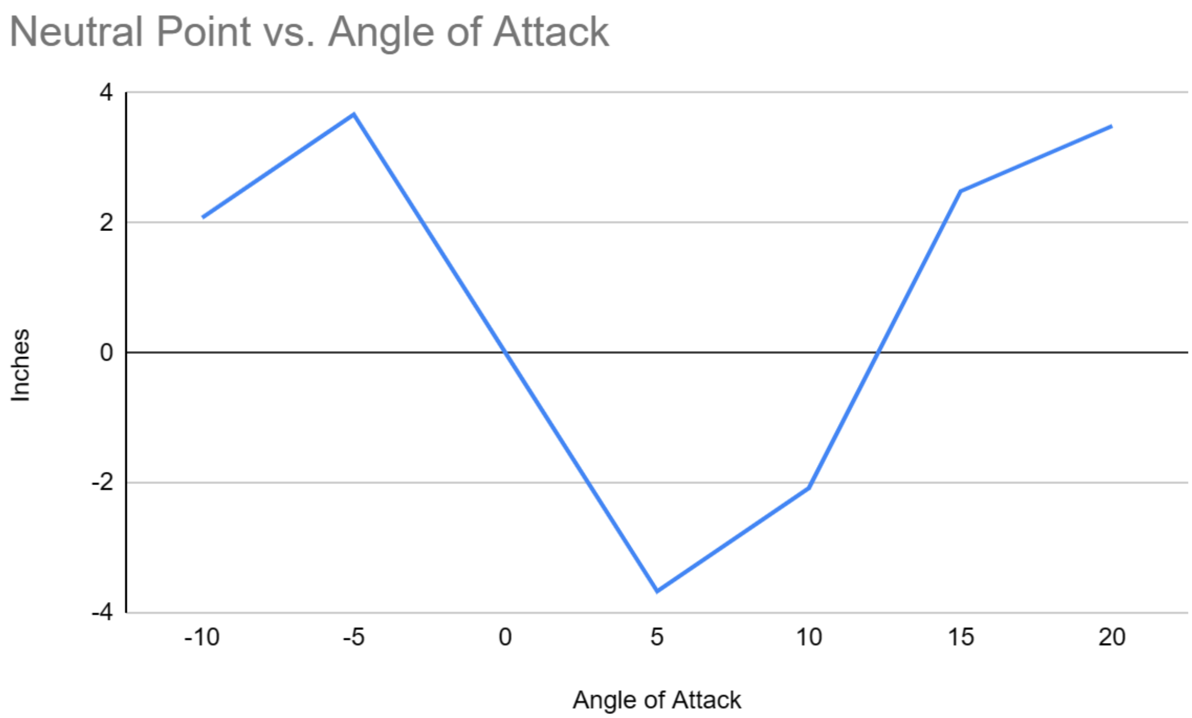
BR (Initial) I certify that the team has used the Aero Design inspection checklist to inspect their aircraft before arrival at Technical Inspection and that the team will present this completed checklist, signed by the Faculty Advisor or Team Captain, to the inspectors before Technical Inspection begins.

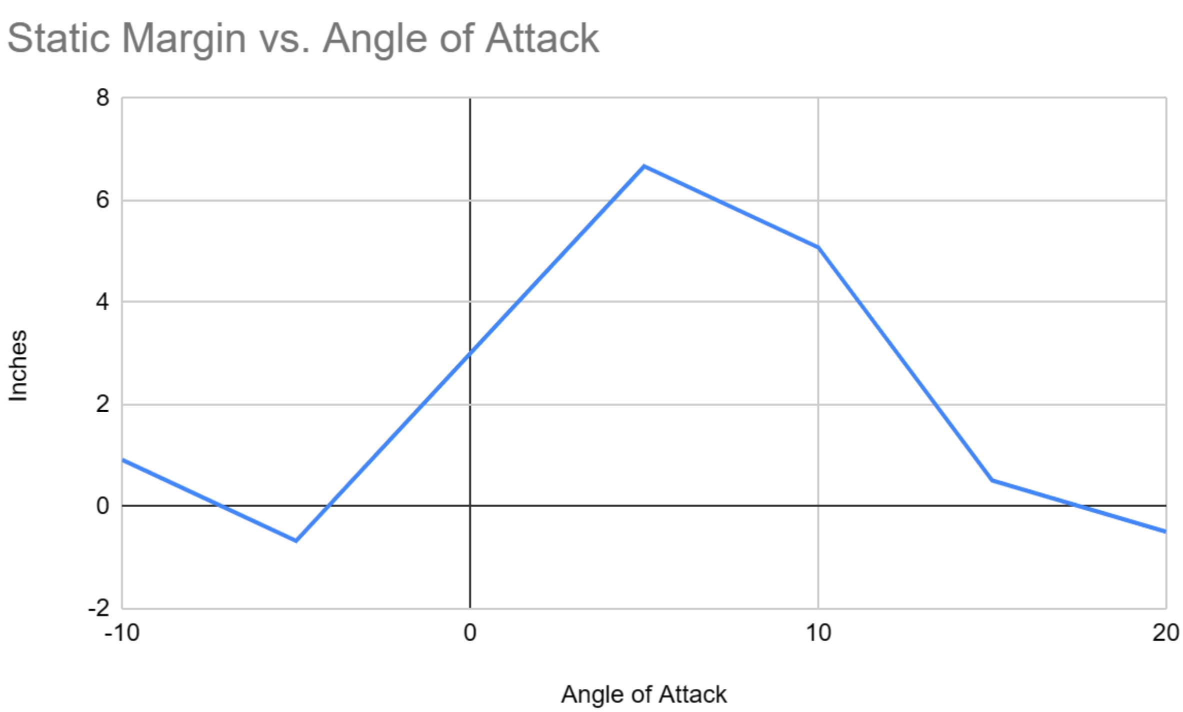
Brad Regez
Signature of Faculty Advisor   Date: 01-24-2024

Signature of Team Captain   Date: 01/26/2024


Weight and Balance
A Cobra C3515/14 | 0.434 lbs (0 in)
B Spektrum 2200mAh 30C 3s | 0.381 lbs (18.6 in)
C Payload | about 4.1 lbs (15.6 in)
D Center of Gravity with and without Payload | 15.6 in
NOTE: The electronics, payload, and motor were all placed to place CG 15.6in from the datum point. Each servo used was the same make/model.
DATUM
Motor
Chord Length: 12in
Summary Table
Wingspan | 48 in
Wing Area | 40.5 in
Aspect Ratio | 1.310
Empty Weight | 8.96 lbs
Battery Capacity | 2200 mAh
Motor Model/Make | Cobra C3515/14
Motor KV | 950 RPM/Volt
Propellor Manufacturer, Diameter, Pitch | APC 15 inches, 4
Servo Manufacturer, Model Number, Torque Spec. | Spektrum SPMS3A500, 74oz/in
Univertity OF West Florida
TITLE:
The Odyssey
DRAWN Bryson 01/27/24
MATERIAL
Birch, Lauran Hardwood
SIZE B
DWG. NO. 01
SCALE: 1:20
SHEET 1 OF 1
DO NOT SCALE DRAWING

Technical Data Sheet





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CAD - Computer Aided Design

CG - Center of Gravity

SGA - Student Government Association

UWF - University of West Florida

OUR - Undergraduate Research

1 Introduction

1.1 Understanding Requirements

The 2024 SAE Micro Class competition challenges engineering students to design an electric RC aircraft to achieve a plethora of design and performance requirements. With no wingspan limitation, the aircraft is restricted to an electric propulsion motor powered by lithium polymer batteries with no more than four cells and must use a 2021 or newer version 450-watt power limiter provided by Neumotors. However, due to the scoring equations, the aircraft must have a minimized wingspan. The plane must have one liquid payload container that consists of liquid water. The payload is required to hold a minimum of 67 fluid ounces of water and be able to drain in one minute or less. The payload cannot be altered as it must be plain liquid water and must be fully enclosed with the exception of one hole to fill and one to drain the water. In order to qualify, the aircraft must take off within 100 feet and land within 200 feet after completing a full circuit around the designated course [1].

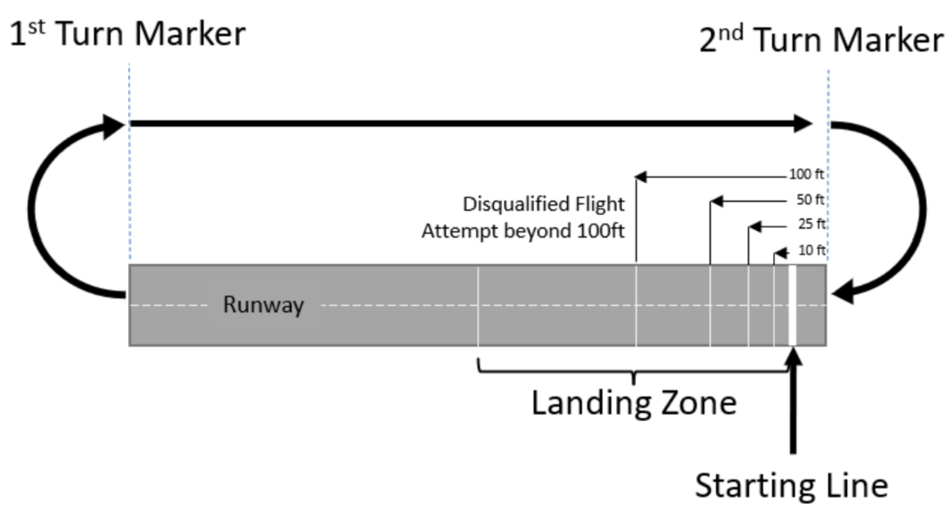


Figure 1: SAE Aero East Flight Circuit

Out of all the requirements, the ones that specifically drove the design were the liquid cargo compartment as well as the wingspan and weight of the final design. Due to liquid dynamics, one of the best ways to ensure that the center of gravity does not shift throughout the flight is to fill the container all the way to the top so that the payload acts as a solid body. This means the team had to decide on a specific amount of water to maximize the design. This, in turn, made the team question the wingspan-to-fuselage length ratio to optimize the lift generated by the aircraft.

Another important aspect is that the liquid cargo must be drained in under one minute. If this isn't achieved, the flight score is voided. This means the competition requires multiple concepts to work together in order to get an actual final score adding risk to the overall project as a whole.

1.2 Understanding Risk

There are many risks that the UWF Argonautics team dealt with this competition season [1]. For one, the Argonautics team is composed mostly of mechanical engineering majors, without any aerospace majors. Due to this, most of the team lacked applicable aerodynamic knowledge. Compared to other

Risk Assessment Table — Argonautics Team, University of West Florida

Risk	Likelihood (1-5)	Consequences	Risk Rating	Action
Insufficient Knowledge	4	-Unable to design a competitive aircraft	5	-Research Trip -Invited Speakers -Assign sub-teams research.
Manufacturing implementation failure	2	-Unable to manufacturer a plane	3	-Assign team members to research manufacturing techniques.
Landing Gear Failure	2	-Flight attempt can not be scored	5	-A subteam of students implemented their ideas together to manufacturer landing gear with a high factor of safety.
Structural Failure	1	-Aircraft destruction	5	-Trade studies of materials were conducted.
Flight stability failure	4	-Possible aircraft destruction	5	-Implement a gyro in the aircraft.
Take Off Distance Failure	2	-Decreases the amount of scorable Flight attempts	5	-Take off distance analysis using excel solver and real world testing to identify any discrepancies.
Aircraft Crash	5	-Can not compete with unflyable aircraft.	3	-Team members attending competition are taught how to fix possible aircraft issues.
Over Budget	1	-Cannot order parts and cannot manufacture plane	5	-Flyers for donations were created. -Fundraising was conducted at events.

Table 1: Risk Assessment

teams with an aerospace program, this puts us at a disadvantage. The team attempted to mitigate this risk by assigning independent research to each subsection. Team members from previous years who are still students were also invited to come and speak about their respective knowledge on the subject. A research trip was conducted to expose the team to real-time aeromechanics as well. This was all done to help with the knowledge gap.

There was also a risk of the plane failing during the competition. There could be failures with the manufacturing implementation, landing gear, structure, flight stability, and take-off distance. Many of these failures could result in an aircraft crash. In order to reduce the chance of any of these risks, subteams with specific focuses were created. The landing gear subteam focused on reducing the chance of the landing gear breaking, and the other subteams did the same with their corresponding field. This should minimize the chance of any of these failures occurring.

Another risk the team faced was with the budget. A limited budget does not allow for high-quality materials, and the team can only afford for a small number of the team to go to competition. To help with this, the team organized a fundraising effort throughout the year. Flyers were created and donations were continuously asked for at every event.

1.3 Project Overview

For optimized team efficiency, the team was divided into a subteam style grouping utilizing a hierarchy of leads from subsequent subteams. The team lead is where the chain of command starts, where the position is in charge of organizing the team meetings as well as overseeing all design, testing, and manufacturing of the entire aircraft. From there, the team was broken up into sub-teams that focused on the most important aspects of the plane [2]. The team is first divided into two main groups: simulation and analysis. Analysis includes the framework that was in charge of designing the base of the plane as well as deciding the most stable and durable material for the frame, control and stability which focused on the math side of the aircraft like lift and control surface, and landing gear. The landing gear was included due to the hindsight from previous competitions that proved the idea to be the most difficult for the team. Simulation includes physical testing as well as computer simulations. While not on the main subteams, the team also consisted of a budget manager, a taskmaster who was in charge of knowing the rules and any relevant information, and a group that worked alongside the capstone team working toward an aircraft for a separate competition in order to pass on knowledge and teach the upcoming team.

Figure 2: Argonautics Organization Chart

` Another way the team optimized the efficiency of its design was by sticking to a designed schedule highlighting the most important benchmarks of the year [3]. To enforce this, the team lead along with the subteam leads worked with their team members to complete said tasks as well as get any new members up to speed on aerodynamics and the scope of the project. For the most productivity, each person was placed into their area of proficiency.

Financially, in preparation for the 2024 SAE Aero East Competition, the team divided the budget into two separate components. There was one budget for the project and the other for competition. The project budget included all the expenses for new parts, materials, and tools that were necessary [2]. The

		Team Advisor:	Dr. Regez					
		Team Lead:	Alyssia Bryson					
			alb182@student.uwf.edu					
	Analysis				Design			
Simulation	Physical Testing			Framework	Landing gear		Control/Stability	
D'Andre Walden	Brett Brustad			Hayden Pursell	Brett Brustad		Kaitlyn Williams	
djw43@students.uwf.edu	btb28@students.uwf.edu			hop4@students.uwf.edu	btb28@students.uwf.edu		krw63@students.uwf.edu	
Ashley Creighton	Aza Boykin		Design, Build, Fly	Kassandra Gartman	Aza Boykin		Joseph Pusateri	
abc149@students.uwf.edu	akb57@students.uwf.edu		William Emiro	kjg45@students.uwf.edu	akb57@students.uwf.edu		jap139@students.uwf.edu	
Kamran Bineshtarigh	Joseph Pusateri		woe1@students.uwf.edu	Caiden Patton	Hunter Wagner		Joel Gonzalez	
kb208@students.uwf.edu	jap139@students.uwf.edu		Liberty Mclean	cap118@students.uwf.edu	hcw18@students.uwf.edu		jgl93@students.uwf.edu	
Hunter Wagner	Camden Chambers		lrm53@students.uwf.edu					
	cmc169@students.uwf.edu		Kamran Bineshtarigh			Budget Shadow/Social Media		Budget:
	Hunter wagner		kb208@students.uwf.edu			Liberty Mclean		Connor Yourist
	hcw18@students.uwf.edu					lrm53@students.uwf.edu		chy3@student.uwf.edu
			Task Master:					
			Kaitlyn Williams					
			krw63@students.uwf.edu					

project's total, listed in the table below, was $1,620.68. The team was able to reuse and repurpose parts and materials from the previous year. The competition budget included all the planned expenses for traveling, food, and housing while at competition for a total of $2,471.65 [3]. The budget was essential to tracking expenses and knowing what other funding was required to continue our project.

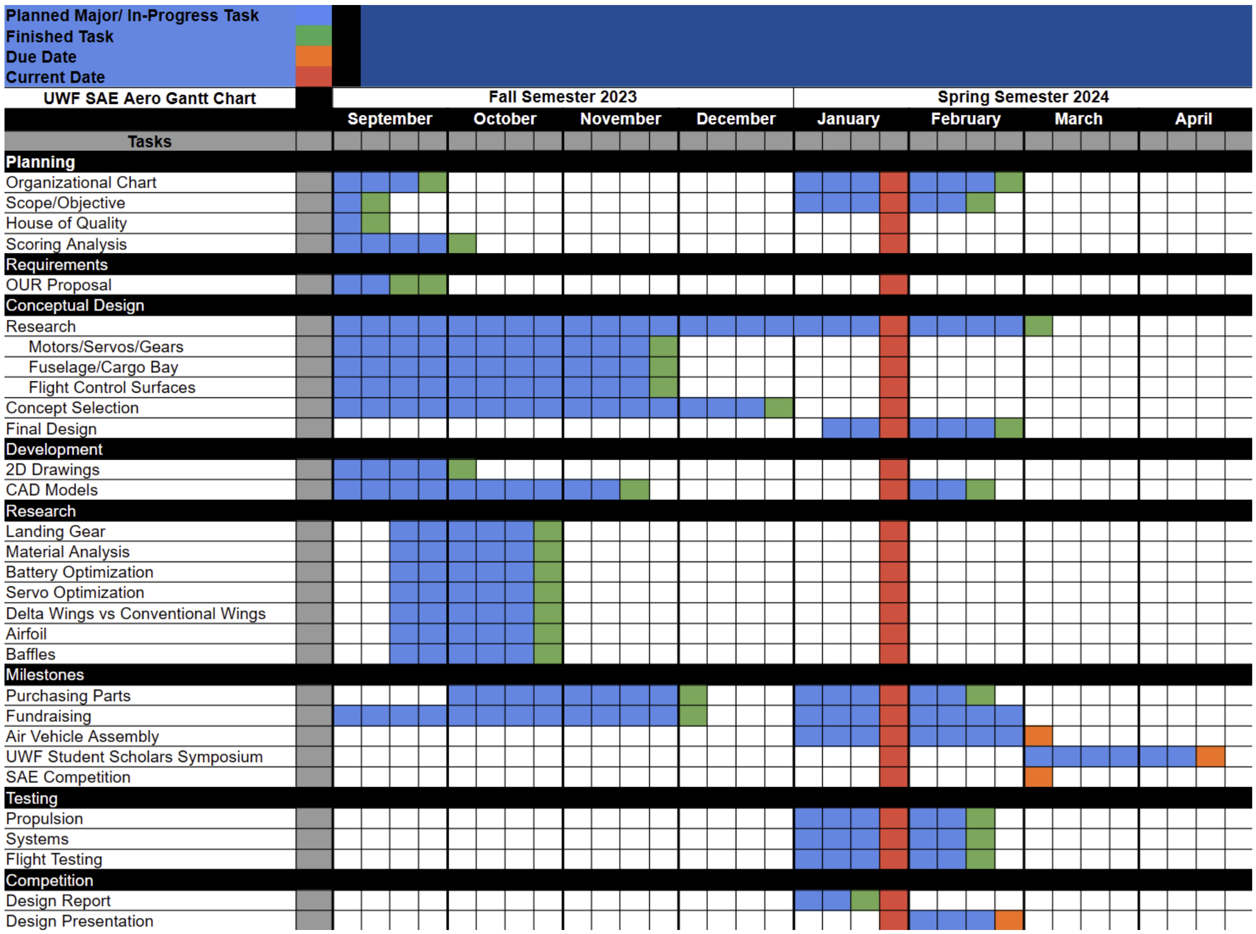


Figure 3: Gantt Chart

Item	Cost	Quantity	Total Cost
Registration	$1,500.00	1	$1,500.00
RC Plane Wheel Collars	$12.99	1	$12.99
RC Plane Wheels	$9.49	1	$9.49
1/4in Birch Hardwood	$46.28	1	$46.28
1/4in Lauan Hardwood	$25.96	2	$51.92
		Total	$1,620.68

Category	Cost
Vehicle Rental	$260.00
Gas	$452.83
Housing	$894.82
Meals	$864.00
Total Travel Budget	$2,471.65

Tables 2 and 3: Material Cost and Travel Budget

With the team's two budgets in place, the team needed to acquire the funding. The University of West Florida (UWF) Mechanical Engineering Department allotted the team $1,500 and up to $500 to match any external funding. The team was awarded $105 from the UWF Office of Undergraduate Research (OUR) and had $800 from fundraising through local companies. The team is now working with OUR and the UWF Student Government Association (SGA) to apply for the OUR and SGA

Travel Fund. The team will use both travel fund awards to finance our attendance at the SAE Aero Design East competition.

2 Analysis

2.1 Configuration Selection and Trade Studies

Initially, in the design process, the team performed research to determine the ideal framework and payload configurations concerning the competition requirements. The design and location of the payload container were a primary consideration; the aircraft stability is highly dependent on how the liquid in the payload container changes the center of gravity. The team chose to utilize a cylindrical tank with baffles for the payload container design, referencing existing water-carrying vehicles and fuel tanks such as those in water-bombers and tanker trucks.

After determining the payload container dimensions, the team chose framework configurations that would best provide stability and lift to accommodate payload slosh and weight. With stability in mind, a standard monoplane arrangement was selected as the base for the design. A high-wing

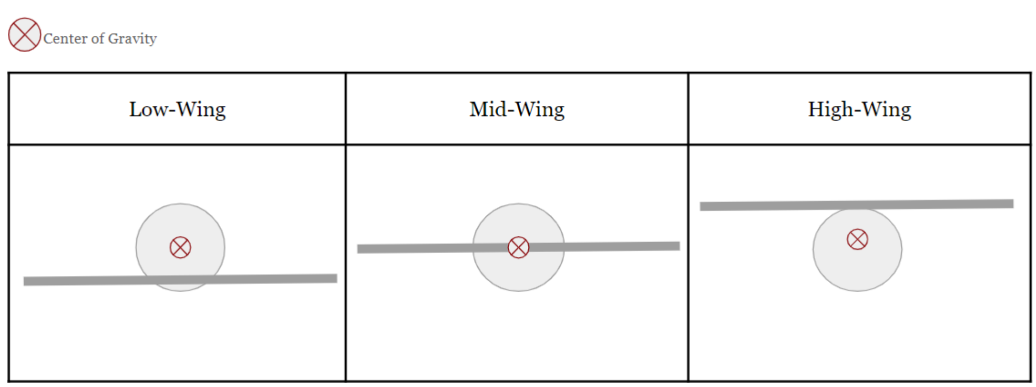


Figure 4: Center of Gravity Comparison for Wing Configuration

configuration was determined to perform best for stability. The center of gravity in high-wing aircraft is located below the wings [4], which increases lateral stability.

The team chose a tapered chord wing to decrease the total weight of the structure and for aerodynamic efficiency. For efficient construction, the team elected to use a conventional tail. The team compared three common fuselage structures: truss, monocoque, and semi-monocoque. While lightweight, truss frames are known to lack rigidity, monocoque structures have excellent stability but are very heavy. A semi-monocoque design – which utilizes elements from both truss and monocoque frames – was selected for the fuselage due to its resistance to buckling and overall structural stability; the payload container added additional weight to the fuselage which needed to be supported. Information collected during research further determined specific dimensions and design features {3}.

2.2 Scoring Analysis

The team's analysis was performed utilizing the scoring equations provided by SAE in their design rules for Design East 2024 [1].

$$Flight\ Score = FS = 3 * W_{Payload} * M + Z$$

$$M = \frac{11}{(W_{Empty} - 1)^4 + 8.9}$$

$$Z = B_{Takeoff} - S^{1.5}$$

Equation 1: Flight Score Equation

Using the specifications given in the SAE Aero Design 2024 challenge and rules, as well as a baseline developed with the data from the previous year's competition, the team determined how altering each aspect of the aircraft design and performance in the equation would affect the overall flight score. Using Excel to compare flight scores based on variable alterations, the team found that minimizing the empty weight of the aircraft and wingspan would have the greatest positive impact on the score [5]. By altering features such as choosing lighter materials, the team could reduce the overall empty weight and increase the value of variable M in the scoring equation. The team could also choose to design a fuselage just large enough for the payload and necessary components to decrease the aircraft's minimum wingspan improving the value of Z in the scoring equation.

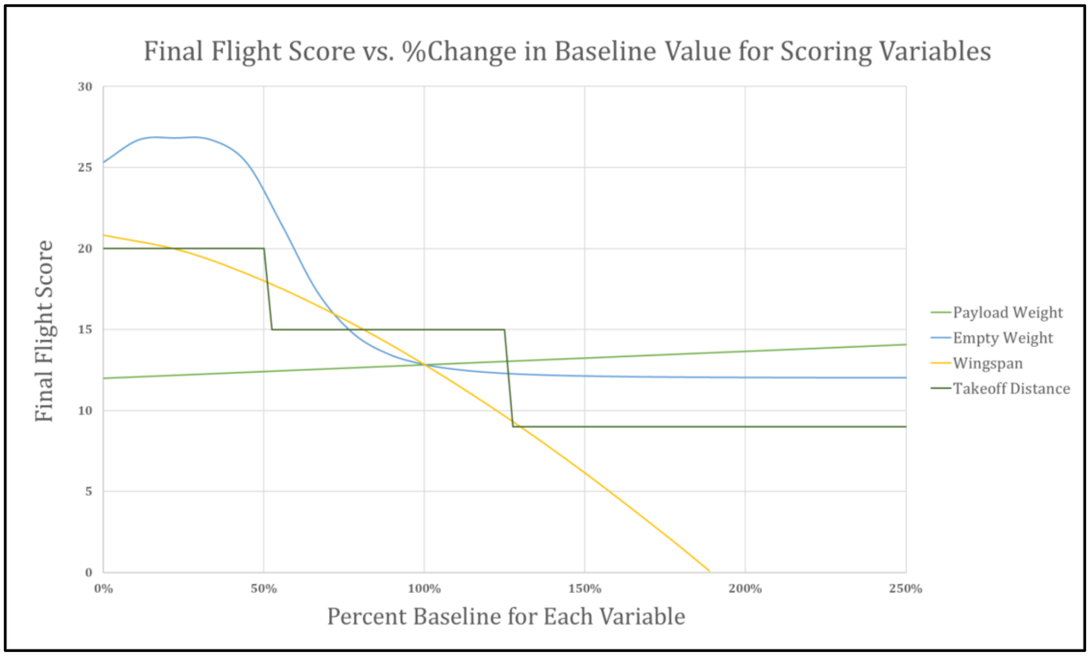


Figure 5. Graph of Flight Score vs. % Change of Variable from Baseline

Another important variable noted is the takeoff distance; the aircraft can only travel about 25 feet without taking off before the flight score dramatically decreases. With special regard for the minimum challenge payload weight of approximately 4.1 pounds, which we determined based on the requirement of carrying 67 fluid ounces of liquid water, an optimal score can be achieved with an ideal balance of the variables. The ideal aircraft design involves a lightweight structure minimizing empty weight that is also able to support the weight of the payload. Choosing a smaller wingspan increases the flight score, but can not be at the expense of the lift necessary for the loaded plane to take off in fewer than 25 feet. With the additional challenge of carrying a liquid payload, the team intended to alter and improve upon the previous year's design specifications and earn a flight score at least equal to that of last year.

2.3 Refinement

After our original design, the members of SAE Aero needed to introduce a new space for our integrated electronics. This included power for the propulsion system, the in-flight control surfaces, and the steering mechanism for ground travel. The initial design of the remote-controlled aircraft was completely slick. This decreases drag and can often increase overall lift.

Through careful optimization, we included space where the batteries for said propulsion, wiring, and flight controls could be housed. Similar to that of any regular aircraft, hydraulic and wired systems are stored within wings, fuselages, or other active parts of aircraft. With our remote-controlled aircraft, weight distribution plays a tremendous role in the aerodynamic capability and optimal maneuverability. Our center of gravity (CG) only changed minimally in the aft direction along the longitudinal axis and maintained a nearly exact CG along the lateral axis.

This slight change of CG will allow the pilot more grace when in critical phases of flight such as takeoff, turning, and landing. With a CG that lies further aft, a change of direction becomes slower and can be achieved while holding a higher angle of attack. This is helpful to the pilot in ways to not pass critical speed or risk of destabilization.

2.4 Propulsion System

2.4.1 Motor Selection

Based on this year's 450-W, 2021 or newer power limiter requirement, the team selected the Cobra 3515/14, Kv = 950 RPM motor, with the following specifications {4}, {7}:

(Tested) Weight (lbs)	0.43
(Manufacturer) Weight (lbs)	0.39
(Manufacturer) Maximum Continuous Power for a 3-cell LiPo Battery (W)	490
(Tested) Static Thrust with APC 15x4E Propeller (lb_f)	5.79

These specifications were obtained from manufacturer websites and testing done by the team {8}. The team selected this motor because the maximum power output of the motor is only slightly above the 450-W power limiter required.

2.4.2 Battery Selection

When considering which battery to use, the team sought to minimize weight while guaranteeing that the aircraft possessed enough power to complete at least one full loop around the flight circuit. The team wished to minimize weight for each battery chosen, as this year's rules require the use of two independent batteries; one for the receiver system, and one for the electric motor propulsion system. Minimizing the weight of each of these batteries makes controlling the Center of Gravity much easier. Of particular concern to the team was the amperage of the battery for the electric motor propulsion system, as the majority of the power used by the aircraft would be used by this system (which would, therefore, require a larger battery). The team anticipates a minimum flight time of one to two minutes leading to the decision to use a 2200 mAh battery because at 80% capacity a 2200 mAh battery is capable of operating the aircraft's electric propulsion system for approximately 1.1 minutes at maximum amperage draw. At maximum capacity, a 2200 mAh battery is capable of operating the aircraft's electric propulsion system for approximately 1.3 minutes at maximum amperage draw. The battery is capable of operating the team's selected motor for approximately 2.4 minutes at maximum amperage draw. At maximum capacity, a 2200 mAh battery is capable of operating the team's selected motor for approximately 3.0 minutes {5}, {8}, {9}.

2.5 Finite Element Analysis

The plane model was designed using Solidworks. Using this model, the plane was simulated in the xflr5 software. This calculated the lift coefficient, lift force, drag coefficient, cord length, cord distance, center of gravity, and drag force at 45 ft/s. The table below shows the final design flight characteristics of the plane including coefficient of lift and drag, center of pressure, etc..

alpha	Beta	CL	CDi	CDv	CD	CY	Cl	Cm	Cn	Cni	QInf	XCP
-9.000	0.000	-0.161132	0.001824	0.112166	0.113990	0.000000	0.000000	-0.006616	0.000000	0.000000	13.7160	-0.0283
-8.000	0.000	-0.106059	0.000828	0.099137	0.099965	0.000000	0.000000	-0.034647	0.000000	0.000000	13.7160	-0.1566
-7.000	0.000	-0.046277	0.000174	0.087676	0.087851	0.000000	0.000000	-0.062163	0.000000	0.000000	13.7160	-0.3449
-6.000	0.000	0.010558	0.000015	0.074775	0.074790	0.000000	-0.000000	-0.094099	0.000000	0.000000	13.7160	-0.2641
-5.000	0.000	0.080138	0.000435	0.062299	0.062734	0.000000	-0.000000	-0.130270	0.000000	0.000000	13.7160	0.0499
-4.000	0.000	0.178831	0.002152	0.051295	0.053447	0.000000	-0.000000	-0.178536	0.000000	0.000000	13.7160	0.2370
-3.000	0.000	0.295834	0.005882	0.041023	0.046905	0.000000	-0.000000	-0.234705	0.000000	0.000000	13.7160	0.2897
-2.000	0.000	0.435881	0.012728	0.030337	0.043065	0.000000	-0.000000	-0.301865	0.000000	0.000000	13.7160	0.2341
-1.000	0.000	0.580832	0.022610	0.019612	0.042222	0.000000	-0.000000	-0.371474	0.000000	0.000000	13.7160	0.1827
0.000	0.000	0.701730	0.033009	0.014156	0.047165	0.000000	-0.000000	-0.421650	0.000000	0.000000	13.7160	0.1594
1.000	0.000	0.800116	0.042953	0.013302	0.056254	0.000000	-0.000000	-0.453706	0.000000	0.000000	13.7160	0.1499
2.000	0.000	0.880197	0.052018	0.013619	0.065638	0.000000	-0.000000	-0.474852	0.000000	0.000000	13.7160	0.1422
3.000	0.000	0.959016	0.061793	0.014064	0.075857	0.000000	-0.000000	-0.495384	0.000000	0.000000	13.7160	0.1357
4.000	0.000	1.039430	0.072652	0.014380	0.087032	0.000000	-0.000000	-0.516974	0.000000	0.000000	13.7160	0.1301
5.000	0.000	1.121186	0.084611	0.014653	0.099264	0.000000	-0.000000	-0.539558	0.000000	0.000000	13.7160	0.1253
6.000	0.000	1.200841	0.097056	0.015053	0.112109	0.000000	-0.000000	-0.560942	0.000000	0.000000	13.7160	0.1213
7.000	0.000	1.279580	0.110217	0.015533	0.125750	0.000000	-0.000000	-0.581859	0.000000	0.000000	13.7160	0.1176
8.000	0.000	1.357762	0.124147	0.016092	0.140239	0.000000	-0.000000	-0.602542	0.000000	0.000000	13.7160	0.1145
9.000	0.000	1.435075	0.138712	0.016634	0.155345	0.000000	-0.000000	-0.622670	0.000000	0.000000	13.7160	0.1115
10.000	0.000	1.505919	0.152788	0.017019	0.169807	0.000000	-0.000000	-0.638915	0.000000	0.000000	13.7160	0.1086
11.000	0.000	1.572720	0.166712	0.017398	0.184110	0.000000	-0.000000	-0.652918	0.000000	0.000000	13.7160	0.1059
12.000	0.000	1.643980	0.182190	0.018118	0.200308	0.000000	-0.000000	-0.669773	0.000000	0.000000	13.7160	0.1035
13.000	0.000	1.713086	0.197904	0.018902	0.216806	0.000000	-0.000000	-0.685429	0.000000	0.000000	13.7160	0.1012
14.000	0.000	1.777656	0.213155	0.019722	0.232877	0.000000	-0.000000	-0.698545	0.000000	0.000000	13.7160	0.0989
15.000	0.000	1.830728	0.226301	0.020959	0.247260	0.000000	-0.000000	-0.705572	0.000000	0.000000	13.7160	0.0965

Table 4. Xflr5 Data based on Final Model of Plane at 45 ft/s

2.6 Stability and Control

Stability and control surfaces are important factors to consider when designing and constructing an aircraft while also verifying the simulated data. The team utilized many different tools and methods to maximize control and stability of the aircraft. Among these tools and methods are simulation, theoretical calculation, 3D design software, and the study of precedent. The chosen design became a trainer RC aircraft due to its favorable and unique characteristics; namely, its inherent stability. Trainer RC aircraft also typically possess high-wing configurations. This trait of trainer RC aircraft allows the team to place the payload container under the wings and circuitry which, in turn, allows the team to ensure that the Empty CG and CG with payload are in, or close to, the same location. Trainer RC aircraft are also capable of a level of self-correction allowing minimal sloshing to occur without much incident. Additionally, trainer aircraft are capable of flying at low speeds; beginning turns at low speeds, and turning smoothly can decrease sloshing of the liquid payload and, therefore, prevent the aircraft from becoming unstable in turns {1}

2.6.1 Wing Planform

The team used the simulation software xflr5 to design and analyze these control surfaces such as wing planforms. Using xflr5's ability to simulate wing design and effects on a wing, the team determined the best shape and design to optimize lift due to the wings. A tapered wing chord was chosen due to its ability to create a large amount of lift with a relatively easy-to-produce structure. The team decided on a 4-foot wingspan to optimize lift for the tapered-chord design and a 2-foot wide rear horizontal stabilizer to optimize control for wingspan, wing area, and fuselage length. The simulation team then used xflr5 software to simulate, among other values, coefficients of lift and drag for a range of angles of attack from - 9 to 15 degrees for this design [6].

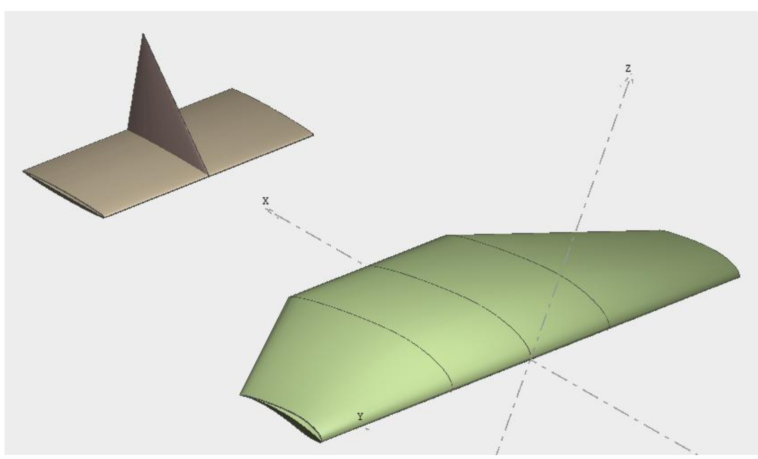


Figure 6: Simulation of Wing Platform

2.6.2 Airfoil

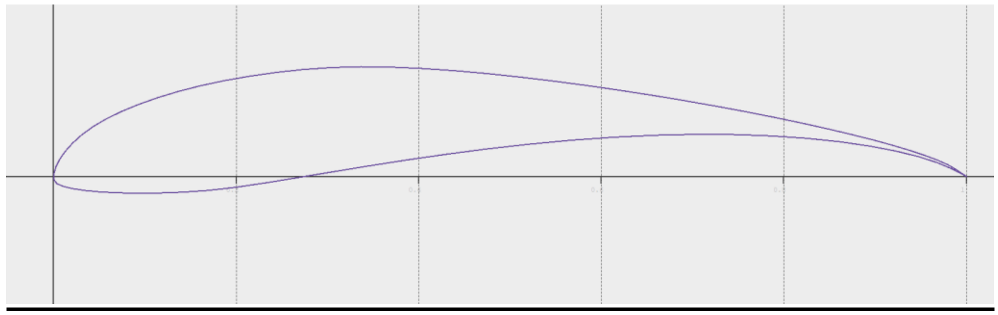


Figure 7: 2D Airfoil Design

The team used xflr5 simulation and airfoil toolbox to choose an airfoil for our final design [7]. Ultimately, it was chosen to create a wing with the Selig S1210 shape and a maximum thickness of 12% because of its high lift-to-drag ratio and stability, which suits the requirement to carry a payload better than alternative airfoils [8,9] {2}.

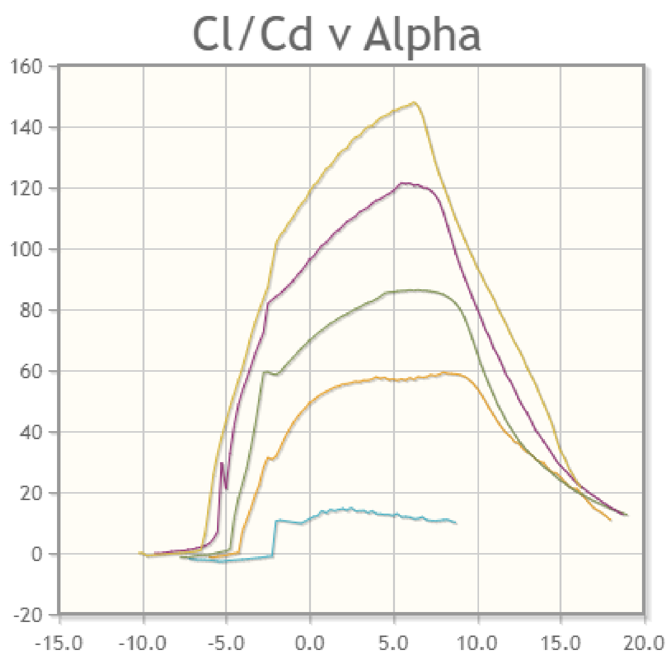
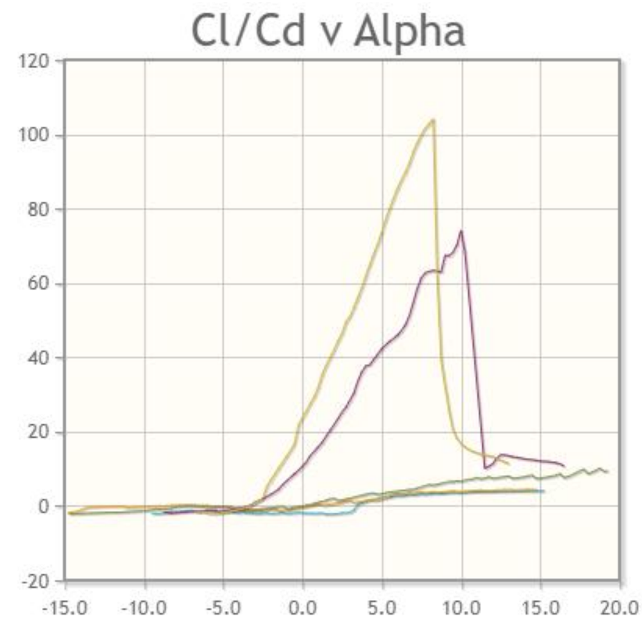


Figure 8: Graph of Angle of Attack vs. Coefficient of Lift over Drag

The simulation team input values characteristic of numerous airfoils into xflr5; however, when simulated, this airfoil's values produced the steadiest numbers across a -9 to 15-degree range in angle of attack, so the NACA16 design for the rear stabilizer, as when this design was simulated, it did not negatively affect the wings' performance and seemed to suit the aircraft's design best.

Figure 9: Comparison Graph of Airfoil L1003



2.6.3 Ailerons, Elevator, and Rudder

Once the team had used xflr5 to optimize a wing design [10] and had obtained dimensions of the optimal design, the control and stability subteam calculated control surface dimensions. Using equations 2, 3, and 4, the team calculated the aileron, elevator, and rudder dimensions for the prototype plane and wing design [11,12,13] {3}.

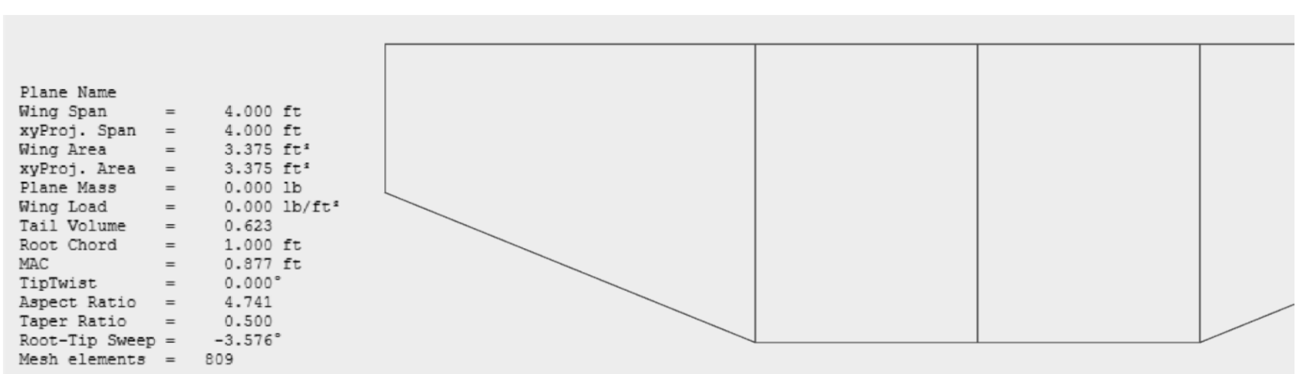


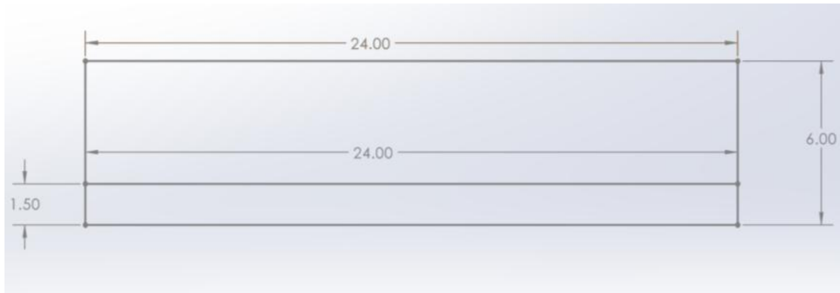
Figure 10: Wing Planform Dimensions and Values

$$AA = (0.06)WA$$
$$EA = (0.25)HSA = (0.625)WA$$
$$RA = (0.25)VSA = (0.025)WA$$

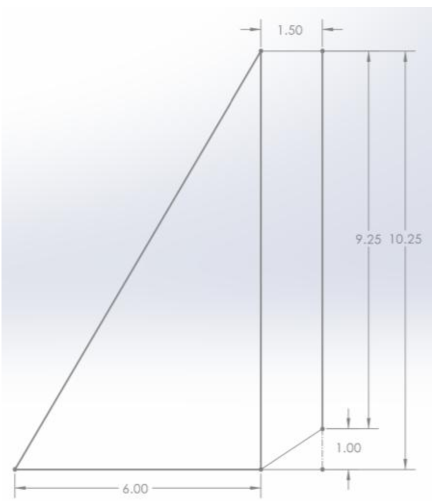
Equations 2, 3, and 4: Aileron, Elevator, and Rudder Area

WA	Wing Area
AA	Aileron Area
EA	Elevator Area
HSA	Horizontal Stabilizer Area
RA	Rudder Area
VSA	Vertical Stabilizer Area

Table 4: Definition of Variables for Control Surface Calculations



Figures 11: Elevator Dimension Sketch



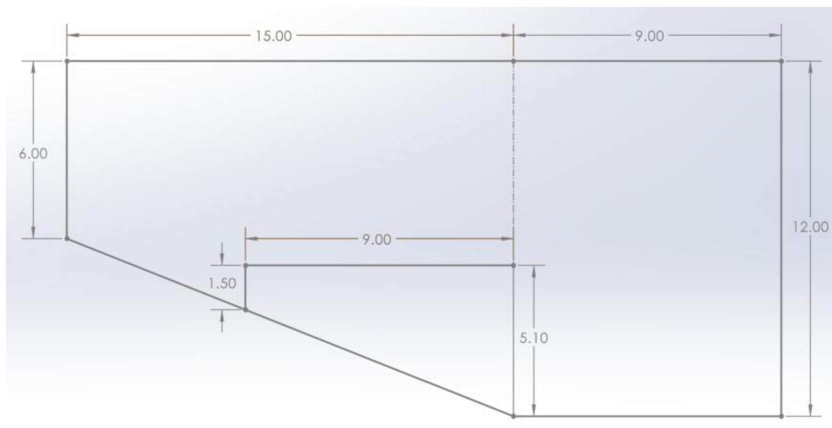


Figure 12 and 13: Rudder and Aileron Dimensions Sketch

While the simulation of the ailerons and elevator performed well with the selected airfoil and vertical and horizontal stabilizers, the initial iteration of the vertical stabilizer and rudder, calculated using equations 2, 3, and 4, did not perform as well as the team believed that it should. Through testing larger stabilizer area and rudder area combinations in xflr5 simulations, the team found that the vertical stabilizer and rudder pictured in Figure 12 performed much better.

2.6.4 Servo Selection

To determine which servos the team could use along these control surfaces, it was necessary to perform calculations regarding the minimum torque theoretically required to move them. To perform these calculations, the free body diagram below was created [14] {4}.

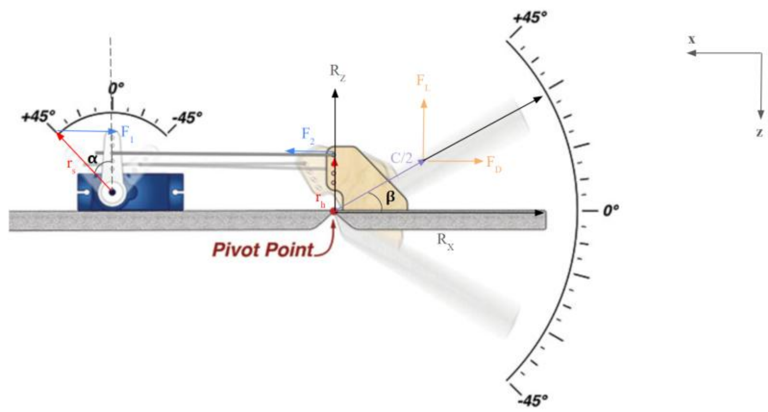


Figure 14: Free Body Diagram of Servos/Control Surface

C	Control Surface Chord (m)
L	Control Surface Length (m)
V	Speed (m/s)
C_d	Coefficient of Drag
C_L	Coefficient of Lift
α	Deflection Angle of Servo Arm
β	Maximum Control Surface Deflection Angle (≅ 30 degrees)
ρ	Density of Air at Room Temperature (≅ 68 degrees Fahrenheit) = 1.204 kg/m^3
τ	Torque (N·m)
M	Moment about the Pivot Point (N·m)

Table 5: Definitions of Variables

This free-body diagram generally represents a control surface, and is used in conjunction with the following assumptions to determine a conservative estimate of torque required {4}:

1. The weight of each control surface is negligible; the control horns are massless.
2. The total moment about the pivot point is zero.
3. F_L acts perpendicular to the control surface at 0 degrees of deflection.
4. F_D acts parallel to the control surface at 0 degrees of deflection.
5. The angle between F_2 and r_h is equivalent to the servo deflection angle
6. The length of the servo shaft is equivalent to the distance from the pivot point to the point at which F_1 acts, r_s
7. The aircraft is not accelerating or rotating.
8. The wing has an angle of attack of 0 degrees.
9. The hinges are frictionless.
10. F_L and F_D act at C/2, the center of mass of the control surface.
11. There are no bends or significant vibrations in the wire attaching the control horn to the servo shaft; $F_1 = F_2 = F$.

$$\boldsymbol{\Sigma}M = (\frac{-C}{2}sin\boldsymbol{\beta})(-\frac{1}{2}\boldsymbol{\rho}C_d V^2 CL) + (-r_h)(F)(cos\boldsymbol{\alpha}) + (\frac{C}{2}cos\boldsymbol{\beta})(-\frac{1}{2}\rho C_L V^2 CL)$$

Equation 5: Substituted Lift, Drag, and Moment Equation

Solving for F, one obtains the following:

$$F = (\frac{-C}{2r_h}\frac{sin\boldsymbol{\beta}}{cos\boldsymbol{\alpha}})(-\frac{1}{2}\rho C_d V^2 CL) + (\frac{C}{2r_h}\frac{cos\boldsymbol{\beta}}{cos\boldsymbol{\alpha}})(-\frac{1}{2}\rho C_L V^2 CL)$$

Equation 6: Force Acting About Pivot Point

$$\tau = cos(\boldsymbol{\alpha})[(\frac{-C}{2}tan\boldsymbol{\beta})(-\frac{1}{2}\rho C_d V^2 CL) + (\frac{C}{2})(-\frac{1}{2}\rho C_L V^2 CL)]$$

Equation 7: Simplified Torque About Pivot Point

From the data [4, 7], values for minimum required torque were calculated for each control surface.

C_L	1.830728; obtained from maximum coefficient of lift and drag data (Figure #)
C_d	0.247260; obtained from maximum coefficient of lift and drag data (Figure #)
V	10 m/s; the speed used to simulate the values of C_L and C_d used
α = β	Assumed to be 15 degrees
Aileron Chord	Assumed to be the largest possible chord length (see figure #)
Aileron Length	9 inches (= 22.86 cm)
Elevator Chord	1.5 inches (= 3.81 cm)
Elevator Length	24 inches (= 60.96 cm)
Rudder Chord	1.5 inches (= 3.81 cm)
Rudder Length	Assumed to be the largest possible length (see figure #)

Table 6: Data Used in Servo Torque Calculations

Ailerons	0.004002 N·m (= 0.56673 oz-in)
Elevator	0.023449 N·m (= 3.32066 oz-in)
Rudder	0.009096 N·m (= 1.28816 oz-in)

Table 7: Minimum Torque Values for Servos

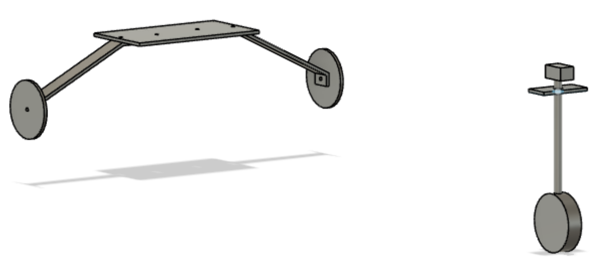
Guided by these calculations, the team selected servos that are more than capable of bearing these loads, even at their lowest voltage {5}. At their lowest voltage, 4.8V, each of the control surface servos has a maximum torque of 48 oz-in, more than enough to move each of the control surfaces, even at higher speeds {5}.

3 Testing

3.1 Landing Gear

When it comes to landing gear the main problems were the ability to handle the weight and the ability for pilots to easily taxi on the pavement. The tricycle design [15] was chosen to make the plane easier to land and take away the risk of crash landing from oversteering. The rear landing gear should be set to handle above 3 times the weight of the plane since some aircraft landings can pull as much as 3 times the force of gravity {10}. With the plane being estimated to weigh about 10 lbs, the rear landing gear should be able to withstand forces upward of 30 lbs. With this in mind, the landing gear subteam was tasked to design fixed rear landing gear that would be able to absorb some of the 30lb weight in order to support the designed aircraft. This was done by using an aluminum extrusion to support the rear landing gear and a very strong steel rod to support the front steerable landing gear [15]. Our team had originally thought of using steel wire to support the back landing gear until testing and theory proved that this was an unwise idea because of the flexibility of the thick steel wire.

Figure 15: A Model of the Tricycle Landing Gear Layout



3.2 Liquid Payload Container

For the liquid payload container, a few different options and their pros and cons were discussed. Initially, the team had the idea of having a balloon inside of the container that the team would fill with water so the water could be drained well within the time limit, while also assisting with making the payload more of a solid body. After a few tests with materials available at the time, it was realized that using the potential energy of the balloon to change the drain time was not allowed per the rules. So, the team removed the balloon part and started research into baffles. The idea for baffles stems from the eighteen-wheel liquid cargo trucks, where it helps them during acceleration and deceleration. Similarly, baffles will be put into the aircraft's liquid payload container to help prevent the "sloshing" of the water during flight, therefore helping prevent changes in the center of mass during flight as well. The team was unable to simulate this motion adequately, so the subteam plans on testing this during more physical testing and test flight. A model of the liquid payload container can be seen in Figure 16.

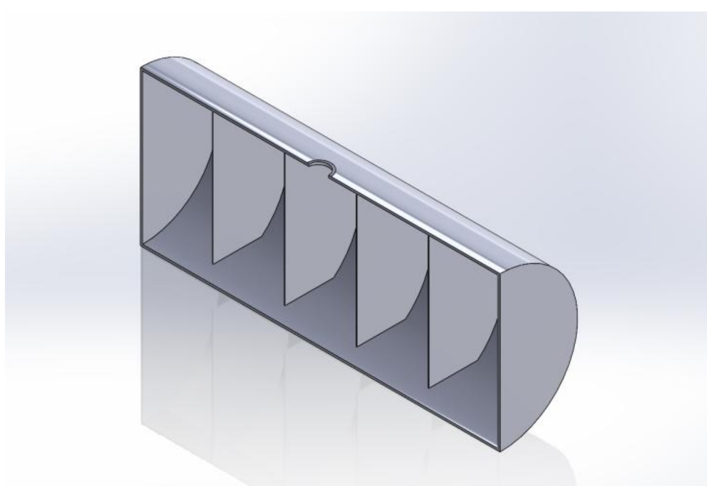


Figure 16: A cross-section of the liquid payload container model

3.2.1 Drain Time

The team also researched and calculated the volume flow rate, mass flow rate, and time to drain for drainage holes of various radii, as it is necessary to have a hole with a radius that allows the liquid payload to drain in a minute or less. By obtaining values for the variables shown in Table 1, the team was able to use the mass flow rate and weight of the water to calculate the time by which all of the water would theoretically be drained from the container. From this data, the team concluded that a single drainage hole of a minimum radius of $\frac{1}{8}$ in. was necessary [Table 9, Figure 17].

$\dot{m}$	mass flow rate
ρ	density
A	area of circular hole; for a circle, $A = \pi R^2$
R	radius of circular hole
$\dot{V}$	volume flow rate
C_d	discharge coefficient, C_vC_c
C_v	velocity coefficient; for water, $C_v = 0.97$
C_c	contraction coefficient; for round aperture, $C_c = 0.97$
g	acceleration due to gravity, approximately 386.0892 in/s^2
H	height of the payload container when the cylinder is oriented horizontally

Table 8: Definition of Variables for Drainage Calculation

$$\dot{m} = \rho V_n A = \rho \dot{V}$$

Equation 8: Mass Flow Rate Equation

$$\dot{V} = C_d A \, (2 \, g \, H)^{1/2}$$

Equation 9: Volume Flow Rate

	Radius of Hole	Number of Holes	Area of Hole (Ind.)	Total Area	Volume Flow Rate of Outlet	Mass Flow Rate of Outlet	Time to Drain	Successful?
1	1/32 in.	1	.00307 sq. in.	0.00307 sq. in.	0.170160 cu. in./s	0.00614 lb/s	710.91 s (11.85 min)	N
2	1/16 in.	1	0.012272 sq. in.	0.012272 sq. in.	0.680642 cu. in./s	0.02558 lb/s	177.73 s (2.96 min)	N
3	1/8 in.	1	0.04909 sq. in.	0.04909 sq. in.	2.72271 cu. in./s	0.09832 lb/s	44.429 s	Y
4	1/4 in.	1	0.19635 sq. in.	0.19635 sq. in.	10.8903 cu. in./s	0.39325 lb/s	11.108 s	Y
5	3/8 in.	1	0.44197 sq. in.	0.44197 sq. in.	24.5133 cu. in./s	0.88520 cu. in./s	4.9348 s	Y
6	1/2 in.	1	0.78540 sq. in.	0.78540 sq. in.	43.5612 cu. in./s	1.5730 cu. in./s	2.7770 s	Y

Table 9: Drainage Hole Calculations for Liquid Drained from a Container

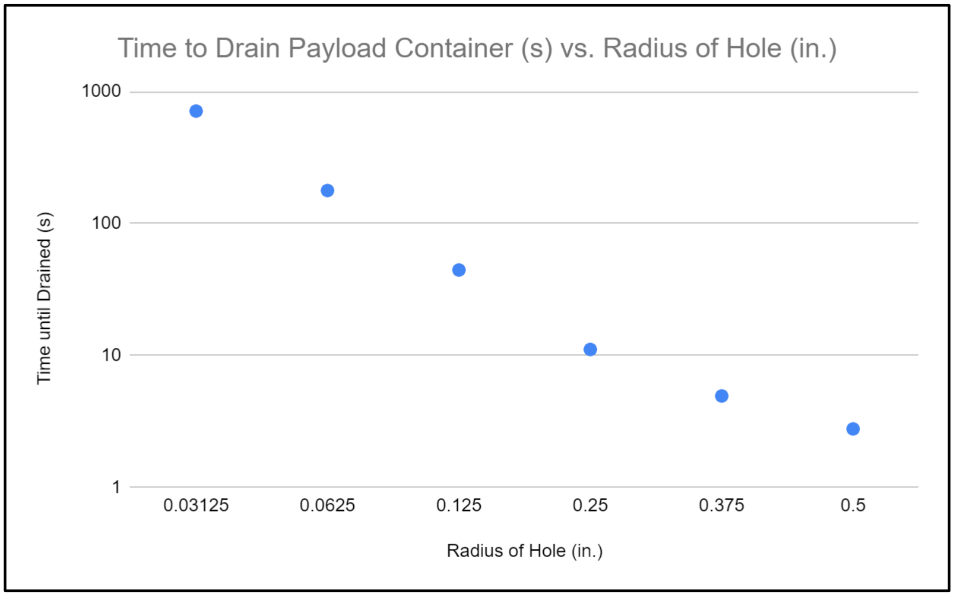


Figure 17: Graph of Relationship between Time to Drain Payload Container and Radius of Drainage Hole

3.2.2 Center of Gravity Shift

During flight, the water inside of the liquid payload container will shift around due to the forces acting on it, such as a hard banking turn or changing the pitch of the plane. The shifting of the liquid in the container will, in turn, cause a domino effect on the center of gravity that the pilot would have to overcorrect throughout the whole flight. To combat this, the team plans on filling the container up as much as possible so it acts as a solid mass instead of being able to shift around in the container, as well as test different positions of the container during the flight by adding velcro strips inside of the fuselage to place the container on. Doing these two things, along with the baffles inside the container, should make the control and stability of the flight better. Further testing regarding this will be done prior to competitions through various flight tests.

3.3 Flight Testing

The final design was finished a short length of time before this report was written. The team plans to test this aircraft design with flight testing at a local flight field specifically for RC aircraft flight. This will include flying with and without a gyro, as in past competitions the location has been very windy for the pilot to smoothly fly the plane, as well as examine the durability of the chosen material. Another test will be done to certify that the framework chosen does indeed match the math and hold up to the weight of about four pounds plus the weight of the plane landing at full impact for maximum safety. This will, in turn, test the landing gear's force-to-weight ratio.

4 Implementation

4.1 Manufacturing

The framework team chose to make the plane out of birch hardwood, lauan hardwood, and ultracoat. Its natural strength-to-weight ratio ensures durability while keeping the overall weight of the aircraft in check, contributing to efficient flight dynamics. Additionally, wood allows for intricate and detailed designs which are needed for the airfoils. The aircraft needed something with high strength and durability to hold a payload of 4 pounds. It was additionally chosen because of it being cost-effective compared to other materials. A laser cutter offered at UWF will be used to precisely cut each piece needed to make the plane. Using solid works each piece can be designed and then transferred to 2d DXF files in RetinaEngraver to put them onto a 12in by 48in section. Once the files are transferred the team can cut the design pieces with the laser cutter and then be able to put the plane together. Using this process, the team can make excess parts if any are damaged before or during the manufacturing process. The aircraft will be using a square rod to attach the wings and the frame together as well as several small rods to make movement possible on the elevators. Finally, once the frame is put together the team can wire the propeller and all of the servos together then finally ultracoat the design completing the building process. Some difficulties Framework has had with designing and manufacturing the aircraft are designing a 3d object on a 2d plane and having to understand how everything will fit together.

4.2 Possible Errors

There are some possible errors that come with manufacturing this micro class aircraft. Since the team has decided to use wood for the main body, there is a risk of the team not using enough glue. The cyanoacrylate adhesive holding the pieces together could come apart during flight due to strenuous flying conditions. There is another possibility that the wood will break from the impact of the plane landing on the ground after not taking into account wind conditions. There is also a risk of the team applying a weak layer of ultracoat. This could affect how stable the plane is during flight. A tear in the ultracoat from improper application could also result in a crash for the aircraft. If the tricycle landing gear is made too long or too thin as well, they can break from the plane's initial impact with the ground. While it is not planned to crash, these details had to be taken into account as the manufacturing process began.

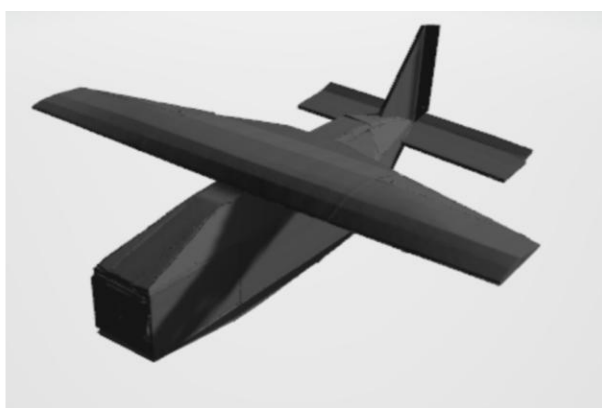


Figure 18: Final Plane Design

Table of References

{1} "Liquid Surge." TruckingTruth. https://www.truckingtruth.com/cdl-training-program/page61/tanker-loading-and-safe-driving (accessed Jan. 26, 2024).

{2} "S1210 12% (s1210-il)." Airfoil Tools. http://airfoiltools.com/airfoil/details?airfoil=s1210-il (accessed Jan. 26, 2024).

{3} "Control Surface Sizing." RCGroups.com. https://www.rcgroups.com/forums/showthread.php?2044090-Control-Surface-Sizing (accessed Jan. 26, 2024).

{4} UWF Argonautics, "2023 Argonautics SAE Report," unpublished.

{5} "HS-85MG Micro Analog Metal Gear Servo." Horizon Hobby. https://www.horizonhobby.com/product/hs-85mg-micro-analog-metal-gear-servo/HRC32085S.html (accessed Jan. 26, 2024).

{6} "Liquid Flow from Containers - Emptying Time." The Engineering Toolbox. https://www.engineeringtoolbox.com/flow-liquid-water-tank-d_1753.html (accessed Jan. 26, 2024).

{7} "Cobra C3515/14 Motor Propeller Data." Innov8tiveDesigns. https://www.innov8tivedesigns.com/images/specs/Cobra_3515-14_Specs.htm (accessed Jan. 26, 2024).

{8} "Cobra C3515/14 Brushless Motor, KV = 950." Cobra. https://www.cobramotorsusa.com/motors-3515-14.html (accessed Jan. 26, 2024).

{9} "50-Amp Switch-Mode BEC Brushless ESC: EC3." Horizon Hobby. https://www.horizonhobby.com/product/50-amp-switch-mode-bec-brushless-esc-ec3/EFLA1050.html (accessed Jan. 26, 2024).

{10} "Hard Landing." SKYbrary.

https://skybrary.aero/articles/hard-landing#:~:text=That%20said%2C%20based%20on%20certification,the%20certified%20maximum%20for%20the (accessed Jan. 28, 2024).