Texas Tech University
2022-2023 AIAA
Design, Build, Fly Entry Proposal

Executive Summary

In pursuance of the American Institute of Aeronautics and Astronautics' (AIAA) 2022-2023 Design Build Fly competition, this report summarizes the goals of Texas Tech University's, Raider Aerospace Society's, Pegasus design team to develop, analyze, manufacture, and compete with a radio-controlled UAV capable of both transporting a heavy electronics package payload and mounting jamming antenna/drag inducer adapters at the end of the wings. The aircraft and all components used in the flight missions must fit within a checked-luggage compliant shipping box with all dimensions summing to 62 in and weighing no more than 50 lbs. The plane must also be able to takeoff within 60 ft. Design metrics include the aircraft's electronic package and jamming antenna capability, out-of-the-box assembly speed, and flight speed.

Through a parameter sensitivity analysis, the optimal design was determined to primarily be maximizing length of the jamming antenna, minimizing course lap time, and maximizing load on wing structure with secondary goal being maximizing electronic package weight of the aircraft. To fulfill this objective, a preliminary design has been developed of a square fuselage with a centrally mounted motor, high-mounted SD 7062 airfoil, T-tail with a tail dragger landing gear, and modular wingtip adapter for the antenna and drag inducer. A test stand facilitating the ground testing of aircraft weight limits was also created. A project schedule has been introduced, with the manufacture flow established and the initial prototype to be started in early November. A maiden test-flight is set to take place mid-January, from which the design will be analyzed, tested, and optimized for the best competition performance by the fly-off in mid-April.

Management Summary

The Raider Aerospace Society (RAS) is the multi-branch aerospace organization of Texas Tech University. Consisting of multiple, separate, design teams centered around a unified management, RAS pursues multiple aerospace related competitions and projects every year. The aeronautics branch, Pegasus, is competing in the AIAA 2022-2023 Design Build Fly competition. Pegasus is established in a hierarchical structure in order to streamline the delegation of tasks and organize the flow of the design process, shown in *Figure 1*. A faculty advisor is available to provide experience and professional insight as well as advice on official university policy and regulations. The president of RAS manages the entire organization across its multiple branches and has executive power on matters regarding Pegasus' operation. RAS' officer board consists of the vice president, treasurer, secretary, and safety officer. The board members work with the different branches to maintain professional standards of operation.

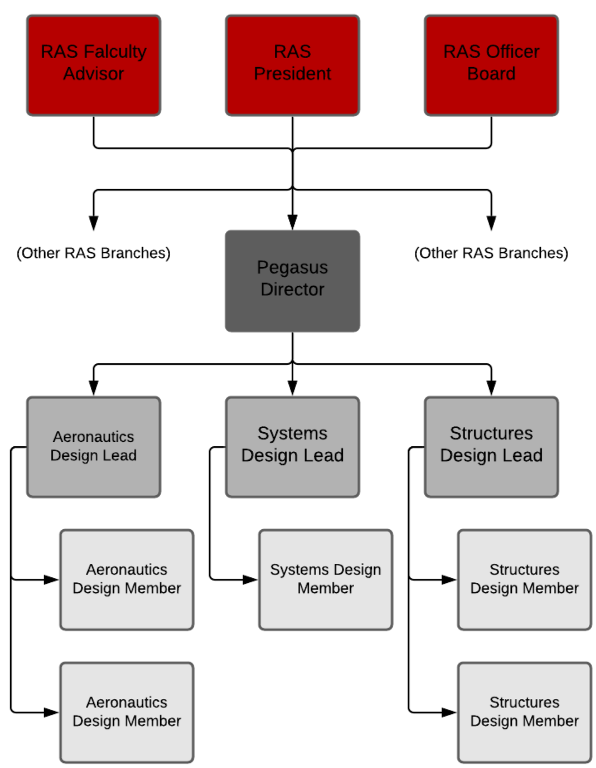


Figure 1. Organization Structure

Shifting into the design divisions, each branch of RAS is headed by a director. The Pegasus director supervises the general design and progress of the project and works with the design leads to establish suitable goals and timetables. Additionally, the director facilitates the collaboration and integration of the separate design teams to work towards a final, complete result, and presents this result back to the officer board in order to source required funding and material. Each of the three design leads guide their respective design teams in the research and development of the plane: assigning the distribution of work, monitoring individual members' progress, and working with other teams to supply deliverables on schedule. Finally, the design members fill each of the teams based on their preference and develop and test different design aspects of the project based on the goals for the week.

The three design teams are aeronautics, structures, and systems. The aeronautics design team handles the design and analysis of the airfoil, empennage, and control surfaces. Analysis includes the use of XFLR 5, Ansys, and OpenVSP to simulate the performance of different flight surfaces under different conditions. The structures team uses Autodesk Inventor and Ansys to develop and test the fuselage, wing ribbing, ground test fixture and any other structure involved in supporting the aircraft. Finally, systems manage the electronics, propulsion, and moving mechanisms within the plane.

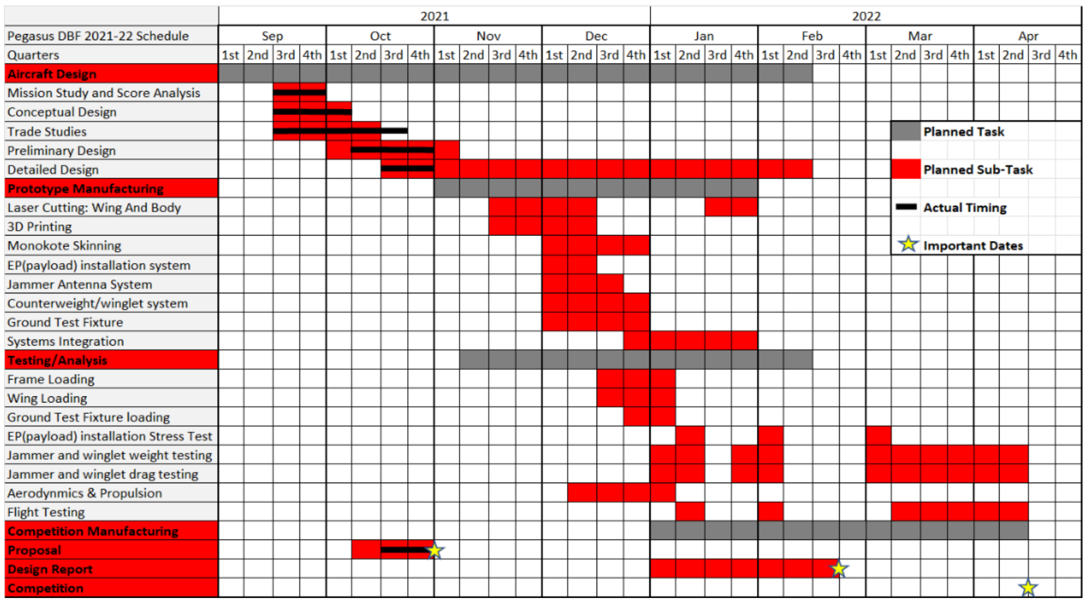


Figure 2. General Schedule

The general schedule maintained by the director is illustrated by the Gantt chart shown above (*Figure 2*). The specific goals for each week are established in biweekly integration meetings, in which the three design teams split or come together to discuss the project's progress and design questions. A summary of the planned expenses accrued through the completion of the project is shown in the budget to the right (*Figure 3*). Much of the spending comes from the travelling expenses, as the manufacture cost of the aircraft is estimated to be around $1,793.24. All the equipment necessary for building the craft (laser cutters, 3D printers, hand tools, etc.) is accessible through Texas Tech University and thus not included in the budget.

	Item/Service	Quantity	Cost(USD)	Description
Components	Brushless Motor/Propeller	1	$ 228.85	
	Servos	10	$ 399.90	
	Propulsion battery	2	$ 105.98	
	Servo Battery	2	$ 38.86	
	ESC	1	$ 99.99	
	Landing Gear	1	$ 30.00	Front Carbon fiber landing gear
	Miscilaneous components	1	$ 100.00	wheels, voltage regulator,fuses, etc.
Materials	Basswood Sheets	10	$ 38.00	12"x12"x1/8"
	Monokote	2	$ 40.00	26"x6'
	Carbon Fiber Spars	13	$ 224.66	10mm, .25 in, .83 in
	Light Weight PLA	1	$ 35.00	800g spool
	ABS	1	$ 23.00	1kg spool
	Steel Tubing	2	$ 60.00	.5"x.5"x6' tubing
	Acrylic Sheets	2	$ 154.00	1/8"x4'x8'
	Aluminum Rods	2	$ 15.00	1/4"Dx12"
	Miscilaneous Materials	-	$ 200.00	Dowels, screws, nuts, epoxy, pvc pipe
Operations	Rental Cars	-	$ 1,100.00	2 cars for 6 days
	Lodging	-	$ 1,500.00	Airbnb for 5 nights
	U-Haul Trailer	-	$ 100.00	Rental for 6 days
	Gas	-	$ 600.00	1400 miles at 30 mpg for $3/gal for 2 cars
Total Cost			$ 5,093.24	

Figure 3. Estimated Budget

Conceptual Design Approach

The aircraft will be judged based on a flight performance score determined from the results of four missions. The objective of each of these missions, the scoring, and the resulting sub-system requirements are presented in *Figure 4*.

Mission	Scoring	Objectives	Sub-System Requirements
M1	$= 1$	Fly 1 lap. Demonstrate general airworthiness of design.	Aircraft must be capable of flight.
M2	$= 1 + \left[\frac{(payload\ weight * \#laps\ flown)_n}{(payload\ weight * \#laps\ flown)_{best}}\right]$	Fly as many laps as possible within 10 min. Score based on payload weight and laps flown.	Fuselage to hold payload. Securement of payload. Large payload weight and high top-speed will maximize score.
M3	$= 2 + \left[\frac{(\frac{antenna\ length}{mission\ time})_n}{(\frac{antenna\ length}{mission\ time})_{best}}\right]$	Fly 3 laps within 5 minutes. Score based on antenna length and mission time.	Antenna to be installed at the end of specified wing and counterweight/winglet to be installed on opposite wing. Securement of antenna. High top-speed and antenna length will maximize score.
Ground Mission	$= \frac{(\frac{total\ test\ weight}{max\ aircraft\ weight})_n}{(\frac{total\ test\ weight}{max\ aircraft\ weight})_{best}}$	Fasten wingtips to ground test fixture and apply test weight to fuselage to test structural integrity of aircraft.	Ground test fixture to fasten to at wing tips. Fuselage and wing structure must be capable of holding test weight. Small max aircraft weight and large test weight will maximize score.

Figure 4. Mission and System Requirement Summary

A score sensitivity analysis was performed to determine the general design parameters which would be most beneficial to pursue based on the competition requirements. The results can be seen in *Figure 5* on the right. Specific design parameters affecting M2, and GM were varied while keeping the other parameters constant. It was concluded that M3 should take priority to maximize score since the score drastically increases when we minimize lap speed and increase antenna length. GM takes next priority while M2 is the least impactful. Thus, it was concluded to minimize lap time, and develop efficient counter winglets and maximize wing and fuselage structure while keeping weight at a minimum.

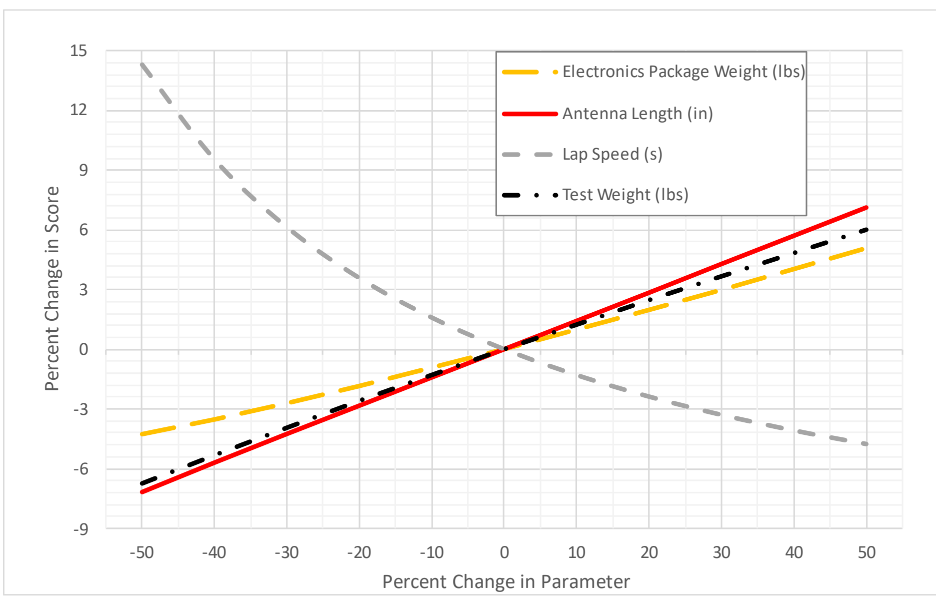


Figure 5. Sensitivity Analysis

Following the design philosophy set by the sensitivity analysis, a shipping box size of 38.5in x 13in x 10.5in was established to help maximize wingspan and chord length while leaving room for miscellaneous components. The preliminary wing design is a conventional, high-mounted, square wing design. The layout was selected based on stability, ease of manufacturing, and analysis simplicity as well as other factors. Once the layout was confirmed, various airfoils were tested in XFLR 5, and the low Reynolds number SD-7062 was chosen to be the best fit based the anticipated max plane weight of 20 lbs, mission metrics, and trade studies confirming the airfoil has desirable properties. Preliminary sizing of the wings determined an active surface area of around 4.86 ft^2, which brought the total wingspan of the plane to about 5.8 ft with a root cord length of 10 in. The flaps and ailerons were designed with a symmetrical airfoil and sized at 15in x 2.5in to provide effective control surface sizing and desirable maneuverability. The flaps have a maximum deflection of 20 degrees providing an estimated 28 lbs of lift on takeoff in M2. For simplicity of design, a wing adapter was made to both hold the jamming antenna and drag inducer depending on flight course direction for M3. The antenna is a PVC pipe varying around 6 in depending on conditions clamped vertically to the wing through the adapter. Mounted to the opposing wing is the drag inducer, equalizing the amount of drag felt on both wingtips. The electronics package is a weight filled 3D printed container of variable weight dimensioned at 7in x 3in x 3in with the fuselage being sized around it. The wings, fuselage ribs, and weight mounting hardpoints are all supported with four, main, carbon fiber spars that run through the top and base of the fuselage. For ease of installation and fast assembly time, the nose cone will be removable to install batteries, the electronics package, and wing servos for all missions. The wing spars are insert into a 3D printed, aluminum reinforced, wing bulkhead with setscrews to be secured to the main body. The wings will have 2 carbon fiber spars with basswood stringers to minimize bending stress for GM and wing tip test. The tail boom extends 20 in from the end of the fuselage into a T-tailed empennage which will be removable for packaging. Liperior 4500mAh 6s batteries were chosen in accordance with the 100 W-h limit for all mission setups. The propulsion system will consist of a centrally mounted motor at the nose of the wing. According to the website ecalc, a thrust of 18.95 lbs was achieved using a 17x10 propeller and the Scorpion SII-4025-520KV motor. Finally, the KST X10 servo will be used to actuate and control the flaps, ailerons, elevator, and rudder. The ground test fixture is a simple steel tube tower with hinged mounting points to eliminate moment stresses. The proposed aircraft can be seen in *Figure 6*.

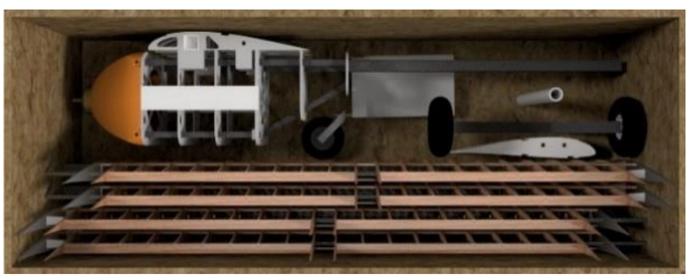


Figure 6. Preliminary Aircraft Design

Manufacturing Plan

Shown in *Figure 7* is the general manufacturing flow for the aircraft. The specific timeline for this flow can be seen in *Figure 2*. Once a detailed design of the aircraft has been produced and all the required components exported to their proper machining files, all raw parts are produced simultaneously across multiple processes. Assembly of the wings and fuselage ribbing structures along with landing gear and other system components are then created. Finally, the critical portions of the plane, specifically the wings and fuselage, will undergo a standard Monokote wrap to create an exterior aerodynamic skin. The outer structures such as the landing gear and empennage are fastened in their respective mounts and then the wings and fuselage are assembled for testing.

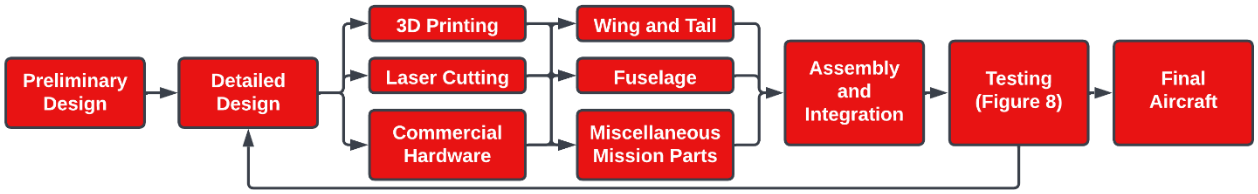


Figure 7. General Manufacturing Flow

To maintain quality during manufacturing, component creation will use a mix of 3D printing, laser cutting, and general metal working. The fuselage ribs and complex geometry parts are to be 3D printed using several types of plastics depending on application. Most of the wing ribs and stringers will be fabricated using laser cutters. To assemble the fuselage and wings, assembly jigs will be created to constrain part alignment. General metal cutting and bending will be used to form rear landing gear and a portion of the wing mount for ease of attachment when exchanging wings.

Test Planning

Each of the design teams will be independently managing the testing of sections specific to their focus. This involves tests to confirm validity of simulated results and analyze performance under un-simulated conditions. Every component of the aircraft will be fully tested for both operating function and safety as it is manufactured and once assembled into the final result. General structural and component checks will be performed before every flight, and RAS' safety officer will also maintain safe practices during aircraft handling and flight. The separate fields of testing are shown in *Figure 8* below:

Category	Test	Purpose	Method
Aerodynamics	Aerodynamic efficiency	Make sure the aircraft design flies stable in flight theoretically before testing a prototype	Use XFLR5 stability tests on aircraft mesh to test wing and tail aerodynamic balance, C_L, and C_D
	Flight test #1	Ensure aircraft is stable, controllable, efficient, and able to complete a lap	A prototype aircraft with no payload or antenna adapter will be flown and observed
	Flight test #2	Ensure aircraft is stable, efficient, and controllable under M2 conditions	Prototype aircraft with maximum payload weight will be flown and observed
	Flight test #3	Ensure aircraft is stable, efficient, and controllable under M3 conditions	Prototype aircraft with wing adapters, jamming antenna and will be flown and observed
Structure	Structural integrity	Ensure aircraft structures can withstand loadings during flight or ground mission	Use ANSYS (FEA) to apply expected loads
	Wing tip loading test	Confirm wing structure is dependable and strong under high g loads	Lift aircraft at the wing tips to simulate a 2.5g loading/apply loading on tail boom
	Ground mission loading test	Confirm fuselage and wing structure is dependable and strong under high centered loadings	Attach aircraft to ground mission test stand and apply weights to fuselage under CG
Propulsion	Thrust test	Choose efficient motor-propeller combination that provides best thrust-to-weight ratio	Use ecalc to analyze best motor-propeller combination and perform static and dynamic thrust tests with different propellers
Components	Landing gear test	Evaluate strength of the landing gear	Conduct drop tests within marginal heights
Ground	Control surfaces	Ensure all control surfaces are working properly within the design parameters	Ensure plug connections are secure and use transmitter for testing
	CG test	Ensure that CG is within the desired location	Lift aircraft from C_L at wing tips to observe if aircraft is level
	Assembly time	Minimize time assembling aircraft	Create as few removable parts as possible. Practice and familiarize with the assembly process

Figure 8. Testing Plans

National University of Singapore (NUS)
2022-2023 AIAA Design/Build/Fly Proposal

1.0 Executive Summary
This proposal details AeroNUS' approach for the design, analysis, manufacturing, and testing processes for the 2023 AIAA Design/Build/Fly Competition.

The objective of this year's competition is to develop an aircraft capable of conducting Electronic Warfare (EW). This aircraft must successfully complete a staging flight, carry an Electronics Package to simulate a surveillance flight and lastly, carry a Jamming Antenna to simulate a jamming flight. After a thorough analysis of the competition's rules and scoring system through a sensitivity analysis, the aircraft will be designed and sized to prioritize and maximize Mission 3 (***M3***) score. Extensive design evaluations and improvements will be conducted for the wings and tail, fuselage, payload, and landing gear before manufacturing prototypes. After working with each component, the plane would be assembled for flight tests. Thereafter, tests for performance are to be held according to Mission 2 (***M2***) and ***M3***.

The validation of the simulation model design would be done based on the results obtained from test flights. From preliminary review of a training plane, Team AeroNUS chose to go with a flying wing design with a wingspan of 6.43 ft to fit into the shipping box of maximum exterior dimensions of 62 inches. As such, the wing will be split into 4 equal sections of 1.60 ft each. Furthermore, the aircraft must carry an Electronics Package more than or equal to 30% of the total aircraft weight. The Maximum Takeoff Weight (MTOW) will be 14 lb while carrying the Electronics Package of 6.20 lb for ***M2***. For ***M3***, a Jamming Antenna of 1.87 ft will be mounted onto the wingtip of the aircraft, with a counterweight on the opposite wingtip.

2.0 Management Summary
2.1 Organization Summary
The 2022/23 AeroNUS team comprises of 10 Seniors, 14 Non-Seniors and 1 Faculty Advisor from the university's Mechanical Engineering department, who specializes in aerodynamics and propulsion. The team is student-led and has regular consultations with the Faculty Advisor.

2.2 Organizational Chart
The team leaders consist of 1 Chief Engineer and 2 Assistant Chief Engineers, who are responsible for key technical decisions and the overall system integration of the various components in the aircraft. The Administration Manager is responsible for team administration including Treasury, Sponsorships, Procurement, Workshop and Publicity. The Manufacturing Lead heads the fabrication processes and determines the proper build methods. The team is further divided into 5 other sub-teams with their respective leaders, who are responsible for overseeing the team's progress and deliverables. The Organizational Chart below shows the hierarchal structure of the team.

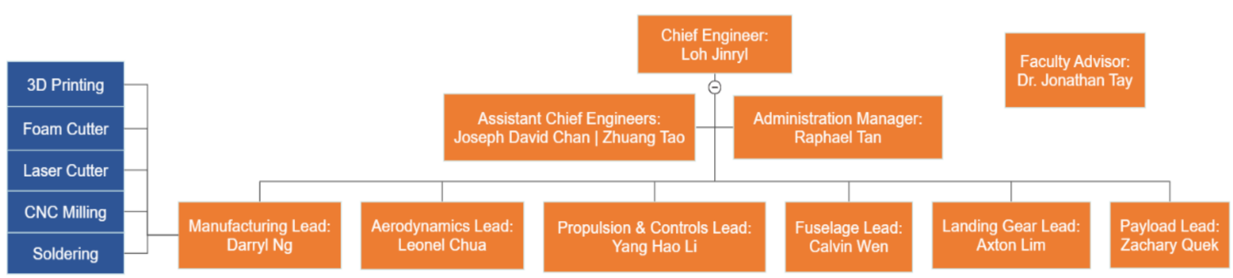


Figure 2.1 – Team AeroNUS Organization Chart

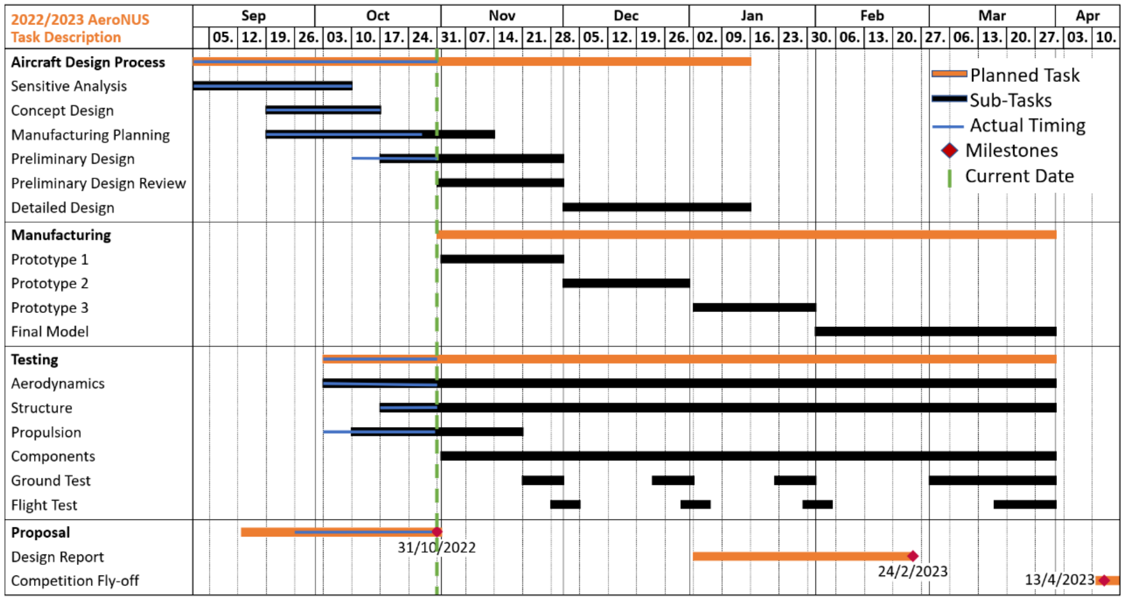
Team	Roles	Required Skills
Aerodynamics	Airfoil Selection, tail and wing design and dimensions	Knowledge in aircraft performance, stability, CFD and XLFR5 as well as analysis of airfoils and wings
Propulsion & Controls	Decides on propeller, motor, battery, and ESC of aircraft, and control surfaces	Knowledge in propulsion calculations, simulations, and conducting static and dynamic thrust tests
Fuselage	Design of airframe and choosing of materials	Proficient in CAD and FEA software to ensure overall structural integrity of aircraft
Landing Gear	Design and construction of landing gear structure	Proficient in CAD and FEA software
Payload	Selection of payload material and securing mechanism	Knowledge in materials

Table 2.1 – Team Roles and Requirements

2.3 Schedule/Major Milestone Chart

The Gantt Chart in Figure 2.2 shows our projected schedule and milestones for the competition and tracks the team's progress. It ensures that ample time is allocated for each milestone for optimal results and that all members of the team are cohesively working together to meet the milestones to complete our best and final aircraft.

Figure 2.2 – AeroNUS Gantt Chart



2.4 Budget

The team receives funding primarily through the university's Mechanical Engineering Department, and additional funds are supplemented through corporate sponsorships and crowdfunding. An estimated financial budget of $21,000 covers aircraft manufacturing, airfare, transportation, and lodging, and is summarized in Table 2.2.

Expenses	Item	Estimated Total Cost (USD)
Aircraft Manufacturing	Aircraft Raw Materials (Wood, Foam, Carbon Fiber, Glue)	$950
	Brushless Motor and Propeller	$150
	Batteries	$200
	Electronics and Servos	$200
	Misc. Hardware	$220
Logistics	Transportation	$420
	Airfare (10 pax)	$16,000
	Accommodation (For the duration of the flyoff)	$1600
	Meals	$1260
	Total:	**$21,000**

Table 2.2 – Projected Expenditure (in USD)

3.0 Conceptual Design Approach

3.1 Analysis of Mission Requirements

The objective for this year's competition is to design, build, and test an aircraft to execute EW missions. There are a total of 4 missions, which consists of 1 ground mission and 3 flight missions. The mission details as well as the sub-system requirements are shown in Table 3.1 below.

Mission	Mission Objective	Payload	Mission Time	Sub-system Requirements
M1: Staging	3 laps with successful landing	None	5 minutes	Aerodynamics & propulsion: Ensure aircraft must be able to complete 3 laps within 5 minutes
M2: Surveillance	Fly as many laps as possible with payload added	Electronics Package	10 minutes	**M2 –** Fuselage, aerodynamics & propulsion: Aircraft must be able to carry as much payload as possible while not compromising speed to achieve the maximum number of laps **M2 –** Payload: Electronics Package should take up the highest percentage of total aircraft weight **M3 –** Payload: Antenna must be securely mounted onto the wing **M3 –** Aerodynamics: Adverse effects of the Antenna must be accounted for without compromising speed
M3: Jamming	Fly 3 laps as fast as possible with Jamming Antenna attached to 1 wing	Jamming Antenna	5 minutes	
Ground Mission	Test weights are added on top of the aircraft in the heaviest configuration	Heaviest Configuration	10 minutes	Fuselage: Aircraft must be structurally strong to withstand as much test weights as possible, whilst not increasing maximum weight by too much

Table 3.1 – Summary of Mission and Sub-system requirements

3.2 Sensitivity Analysis

The scoring functions for each mission are shown in Table 3.2 below.

Mission	M1	M2	M3	GM
Scoring Function	1 for successful flight	$1 + \frac{(Payload\ weight \times laps)_{NUS}}{(Payload\ weight \times laps)_{Max}}$	$2 + \frac{\left(\frac{Antenna\ length}{mission\ time}\right)_{NUS}}{\left(\frac{Antenna\ length}{mission\ time}\right)_{Max}}$	$\frac{\left(\frac{Total\ test\ weight}{Max\ aircraft\ weight}\right)_{NUS}}{\left(\frac{Total\ test\ weight}{Max\ aircraft\ weight}\right)_{Max}}$
Total Score	***M1 + M2 + M3 + GM***			

Table 3.2 – Mission Scoring functions

Based on the sub-system requirements in Table 3.1, as well as the parameters in the scoring functions, the main independent design parameters were identified, namely *payload weight* in ***M2***, *antenna length* in ***M3***, as well as *total test weight* in ***GM***. Mathematical models and relationships between the respective missions' independent and dependent design parameters were established using formulas, as well as estimates based on the team's experience. These mathematical relations formed the basis of the sensitivity analysis for the competition and allowed us to investigate the effects of each independent parameter on the dependent parameter and hence identify which one has the most impact on the mission score, as well as the overall score. Based on the respective scoring functions in Table 3.2, Figure 3.1 below compares the overall sensitivity of each mission with respect to the total score. ***M1*** was excluded from this analysis as it does not contribute much to the sensitivity, and we assumed that it was completed successfully.

From Figure 3.1, ***M3*** is the most sensitive mission, followed by ***M2*** and finally ***GM***. As such, our focus will be on maximizing the score in ***M3*** as much as possible whilst not compromising ***M2*** and ***GM*** severely. Looking at the parameters in ***M3*** (Figure 3.2), *mission time* is the more sensitive parameter and is inversely related to ***M3*** score, which is expected given the scoring function. However, since *mission time* is the dependent parameter, looking at the sensitivity of the *antenna length* in Figure 3.2, a percentage increase in *antenna length* would **still yield** a positive increase in the ***M3*** score since an increase in *antenna length* outweighs the increase in *mission time*. As such, *antenna length* would be maximized to maximize ***M3*** score. However, it must be noted that missions ***M2***, ***M3*** and ***GM*** are interrelated. In this case, the *payload weight* and wing dimensions sized in ***M2*** will have a direct effect on ***M3*** and ***GM***, and may be in direct conflict with each other. As such, the sizing of the aircraft should not be done independently for each mission. Since ***M2*** is most likely the heaviest flight mission, it was sized first followed by ***M3*** and ***GM*** and the optimal configuration was selected for our preliminary design.

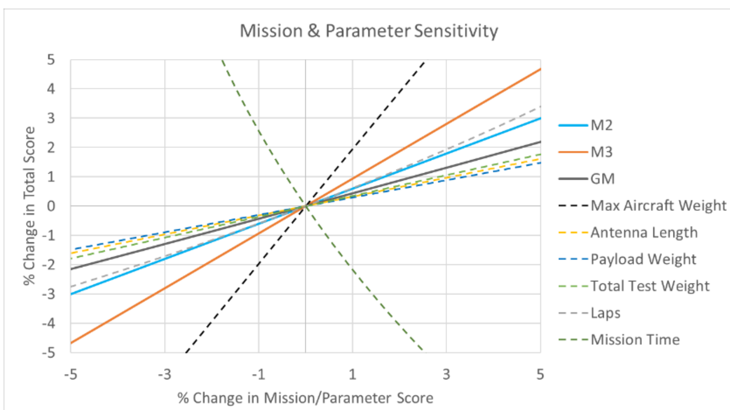


Figure 3.1 – Overall Mission & Parameter Sensitivity

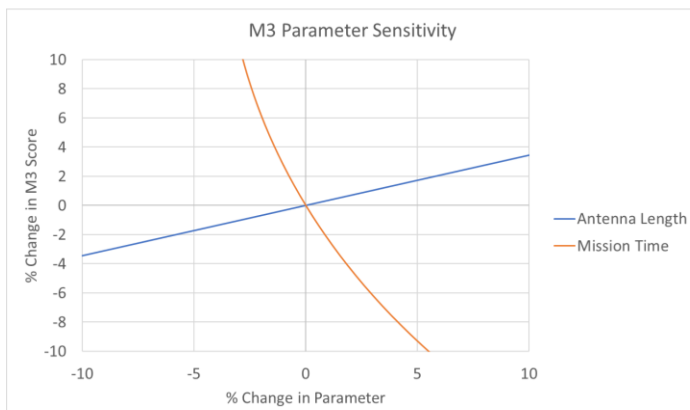


Figure 3.2 – M3 Parameter Sensitivity

3.3 Preliminary Design

Based on the mathematical relations and the sensitivity analysis, the team developed a MATLAB algorithm, AeroSim2023, that computes the optimal aircraft configuration that maximizes our total score. Independent variables of wing aspect ratio (AR), wing area (S), motor power, total aircraft mass and *antenna length* are iterated in AeroSim2023 to obtain the optimal dimensions, whilst bounded by the maximum exterior box dimensions of 62 linear inches. A preliminary sizing was done for ***M2*** which showed that ***M2*** favors a large S to allow for a heavier *payload weight*, as well as a large AR to increase V_{max}. However, ***M3*** and ***GM*** do not favor a large AR since the adverse yawing and rolling effects of the antenna, caused by vortex shedding, in ***M3*** will be increased, as well as the wing structural bending moment in ***GM***. As such, wing AR must be reduced to restrict wingspan. Given this and the overall box constraint, a mathematical function was created and implemented to find the optimal balance between the number of wing sections and AR that fits within the box to maximize S. Figure 3.3 shows the results from AeroSim2023. The results showed that the wing should be broken into 4 sections, with 2 sections for each left and right wing and will have an AR of *4*, S of *10.33 ft²*, and a MTOW of *14 lb*. This gives a wing loading of *1.36 lb/ft²*. From here, a flying wing, without any sweep or taper, was concluded to be the best option given the limited box space. The aircraft will adopt a high wing configuration, utilizing a reflex airfoil to achieve longitudinal stability. The MH70 airfoil was chosen as it has a high $C_{L_{max}}$ of *1.3* and a corresponding V_{stall} of *29.60 ft/s* for ***M2***. This means a lower takeoff speed and lesser time spent on the ground. V_{max} was calculated to be *133.76 ft/s.* The wing will adopt a polyhedral configuration, with a dihedral angle of 15º on the outboard wing section for roll stability. A vertical tail fin, mounted on a carbon fiber boom, will be attached to the rear of the fuselage for directional stability and to dampen the adverse yawing moments of the antenna in ***M3***. Elevons will be used for pitch and roll control. The conceptual design of our first prototype is shown in Figure 3.4 and detailed values and specifications are given in Table 3.3 below.

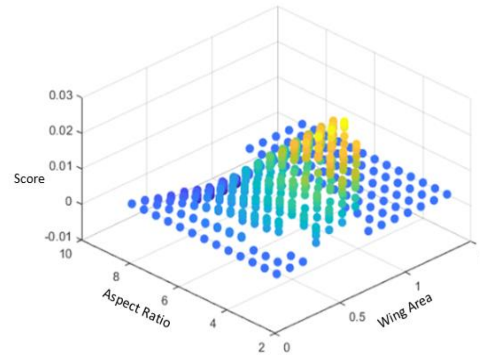


Figure 3.3 – Optimal Sizing Graph

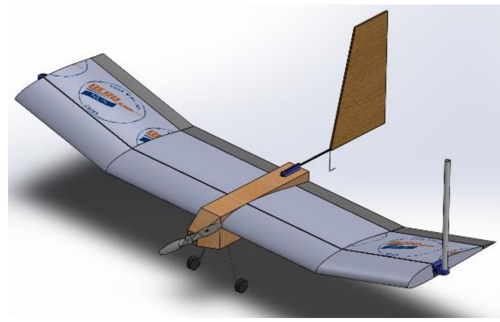


Figure 3.4 – Prototype Design

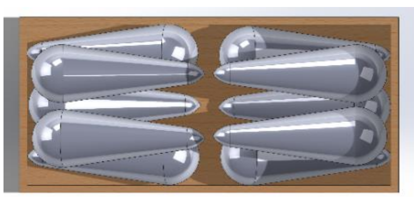


Figure 3.5 – Arrangement of Fishing Weights Inside Electronic Package

For ***M2***, an Electronics Package of 3” x 3” x 6” will be filled with lead fishing weights to achieve the desired weight of 6.20 lb as shown in Figure 3.5. For ***M3***, since maximizing *antenna length* will maximize mission score, it will take the longest length of our shipping box (1.87 ft) and will be secured using a 3D-Printed attachment shown in Figure 3.6, which will be mounted to the wingtips. To balance the antenna’s weight, a counterweight will be attached onto the opposite wing.

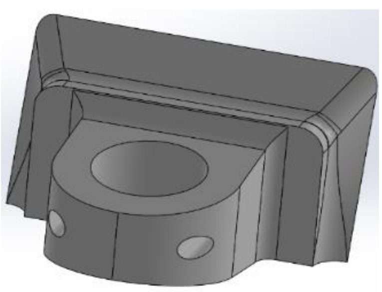


Figure 3.6 – Antenna Adaptor

The propulsion system will adopt a tractor configuration. With a power loading of *113.40 W/lb* and taking into consideration the 100 Wh battery limit, a 6S, 4500 mAh battery was chosen. While this only gives us a flight time of 3.34 mins for ***M2***, it still gives us a higher score compared to flying the entire 10 mins and scaling down the size of the aircraft, which means a lighter payload. The aircraft will be powered by a SunnySky X Series V3 X4120 480kV Brushless Motor, paired with a 16 x 8-inch propeller. The fuselage will be as small as possible to just accommodate the payload and propulsion system, which will be positioned accordingly to give us a static margin of between 5-10% for the flight missions. A tail dragger landing gear configuration will be adopted as it is light and has less drag.

MTOW	14 lb	**Propulsion**		**Wing**		**Tail**	
Dry Weight (including propulsion)	7.80 lb	**Configuration**	Tractor	**Wing Area**	10.33 ft²	**Tail Type**	Vertical Fin
Shipping Box		**Propeller Size**	16 x 8 inch	**Aspect Ratio**	4	**Tail Area**	1.22 ft²
L x W x H	1.62 x 1.87 x 1.62 ft	**Power Loading**	113.40 W/lb	**Wingspan**	6.43 ft	**Tail Boom Length**	1.57 ft
Weight	8 lb						
Fuselage & Payload		**Motor Power**	1793.76 W	**Chord Length**	1.60 ft	**Vertical Tail Volume Coefficient**	0.036
Electronic Package Mass	6.20 lb	**Battery Capacity**	4500 mAh	**Wing Loading**	1.25 lb/ft²	**Landing Gear**	
Antenna Length	1.87 ft	**Propulsion Mass**	2.63 lb	**Airfoil**	MH70	**Configuration**	Tail Dragger

Table 3.3 – Aircraft Specifications

4.0 Manufacturing Plan

4.1 Preliminary Manufacturing Flow

Figure 4.1 below illustrates our team’s proposed manufacturing plan, which includes three intermediate prototypes before fabrication of our final aircraft. MATLAB and XFLR5 simulations will be used for preliminary sizing of aircraft specifications.

The aircraft will then be designed and modelled using CAD software, with its aerodynamic and structural performance validated using CFD and FEA respectively. A thrust stand will be used to select the most efficient propeller for our flight requirements. Preliminary research and wind tunnel tests will also be conducted to analyze the effects of the antenna mounted on the wingtip in ***M3***, such as the Von Karman vortex street.

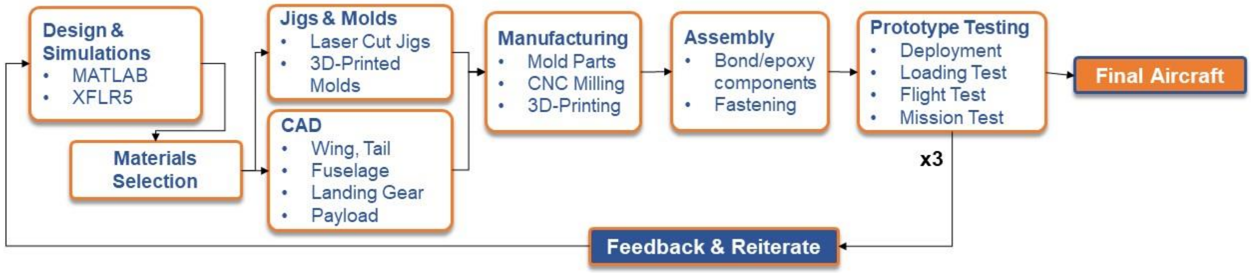


Figure 4.1 – Manufacturing Plan

4.2 Critical Manufacturing Process

After initial analysis done using SOLIDWORKS' structural simulation program, we determined wood to be the primary material for our aircraft structures, namely balsa, basswood, and plywood, which have suitable mass and yield strengths. The use of composite materials (carbon-fiber rods) will also be considered for flight-critical components such as the wings, fuselage, and tail boom (***M2*** and ***M3***). This ensures optimal strength-to-weight ratio of our aircraft, allowing it to withstand maximum loads during the missions all while being lightweight (***M2*** and ***GM***). To ensure that wooden components are consistently fabricated to precise specifications, they will be cut to size using a CNC laser cutter. For hand-cut parts, the use of custom-made jigs will be employed to minimize human error during fabrication. Additive manufacturing will also be used to achieve complex geometry in components like the antenna attachment used in ***M3***. Both the wings and vertical tail will be manufactured using the rib-and-spar method, which provides the best strength-to-weight ratio. Upon completion of the manufacturing phase, propulsion systems and avionics will be fully integrated into the aircraft. Finally, all exposed surfaces will be skinned using *Monokote* film which improves airframe strength while adding very little weight.

5.0 Test Planning

After assembly of each prototype, we will conduct 3 types of tests for validation against their simulated counterparts, as well as to ascertain their safety and reliability during operation. These include preliminary design tests on the propulsion systems, as well as ground and flight tests on the fully assembled prototypes. The first prototype will be used to determine flight characteristics, trim conditions, and the capabilities of our aircraft in carrying the required payloads for ***M2*** and ***M3*** (≥30% of plane's gross weight and antenna mounted on the wingtip respectively), as well as the effects of the antenna on our flight performance. Test weights will be added to ascertain the actual structural margin for the prototypes for ***GM***. The second and third prototypes will be designed to be more efficient and reliable based on data gathered during testing, which will in turn provide further insights to be fed back into the final design of our aircraft. Battery sizes will also be fine-tuned along the way based on actual consumption during the tests to optimize for flight time and performance. These will all culminate in a competition-ready plane of peak performance, which yields the maximum possible score during the competition.

Test	Team In Charge	Equipment Needed	Data/Insights Gained
Preliminary Design Tests			
Propulsion Thrust Test	Propulsion	Motors & Propellers, Force Gauge, Multimeter	More detailed thrust/kh curves, power loading, efficiency curves.
Ground Tests			
Electronics Systems Test	Propulsion	Full Electronics System, RC Transmitter	Functionality of RC propulsion and electronics systems.
Wingtip Test	Aerodynamics	Prototype Wings	Whether wing will pass the required wingtip test with test weights for Ground Mission.
Assembly Test	All Teams	Complete Prototype	Whether entire prototype can be assembled in under 5 minutes.
CG Test	Aerodynamics	Complete Prototype, Weighing Scale	Whether CG remains in acceptable envelope in all scenarios.
Payload Insertion Test	Payload	Complete Prototype, Payload	Whether time taken to insert payload is acceptable.
Propulsion Heating Test	Propulsion	Complete Prototype, Laser Thermometer	Whether mounts can withstand heating from motor and batteries.
Landing Gear Test	Landing Gear	Prototype Landing Gear, Camera, Rig	Whether landing gear can withstand landing loads and if deflection affects aircraft.
Flight Test			
Radio Range Test	Controls	Complete Prototype, RC Transmitter	Maximum range of RC receiver, whether it will pass range test in competition.
Radio Failsafe Test	Controls	Complete Prototype, RC Transmitter	Whether failsafes activate properly when aircraft loses radio signal.
Cruise Test	Aerodynamics	Complete Prototype	Determine flight characteristics based on flight data (cruise speed, turning speed, bank
Takeoff Distance Test	Aerodynamics	Complete Prototype	angle, turning radius, total endurance, takeoff distance)
Turning Test	Aerodynamics	Complete Prototype	Can be used to fine tune battery size and control surfaces, and improve successive
Endurance Test	Propulsion	Complete Prototype, Stopwatch	prototypes.
Ground Handling	Landing Gear	Complete Prototype, Test Mule	Whether landing gear allows for desired taxi and landing characteristics.

Figure 5.1 – Testing Plan

2022/2023 AIAA Design/Build/Fly Proposal

1 Executive Summary

This proposal provides detailed concept design, plans for further design, testing and team management of the University of Maribor's team of the 2022/2023 AIAAA Design, Build, Fly Competition. The team's main objective for the 2022 DBF competition is to design and build an aircraft for the most efficient execution of electronic warfare. The aircraft should be capable of flying with approximately 7 lbs payload and carry a 40" surveillance antenna, mounted to one of the wing tips. The maximum speed in level flight should be about 80 KTAS and the best glide speed, at which the endurance mission will be flown should be around 50 KTAS. The structure should be capable of withstanding the load of no less than 100 lbs and the whole aircraft should fit in the box with the constrained dimensions. This is the fifth DBF competition in which the ADUM team is going to participate, therefore taking into account previous experiences and gained knowledge, the expectations and goals this year are higher. The team's budget is $3.500 for materials needed and $18.150 for transport and accommodation. This year's main challenges are limited battery energy storage, the size of the shipping box, the requirement for multiple wings and a strong antenna attachment. Considering different configurations, a high wing monoplane with a single motor in the front and a conventional tricycle landing gear, has been decided. A single lithium battery pack (LiPo) will be used for the propulsion due to its superior performance per unit mass. This year there is an enhancement of the manufacturing procedures planned, by including additive manufacturing and reinforcing the parts with fiber technology. This way, complex-shaped parts can be manufactured, with superior aerodynamic efficiency and improved rigidity per unit mass. To prepare for the flying missions, the team has conducted a multi-objective optimization using an individually developed Python algorithm. This way, optimal combination of the design parameters for maximizing the total score of all flying missions, has been obtained. An intensive ground and flight testing is planned to further improve the total score and to ensure the early discovery of significant improvement potential and sufficient reliability of all systems.

2 Management Summary

2.1 Description of Organization

The 2022/2023 University of Maribor team (ADUM) consists of one faculty advisor, 7 bachelor students and 4 graduate students and one non-student pilot. Our project leader oversees the project with occasional consultations with the faculty advisor. The project is solely student-led. With this year's growth of members, we departmentalized our team with our senior students leading each department to ensure all regulatory rules are met. Departmentalizing enables our project leader to monitor each department's progress and design review. In addition, it offers better cooperation between each workstation. Our team holds weekly meetings for

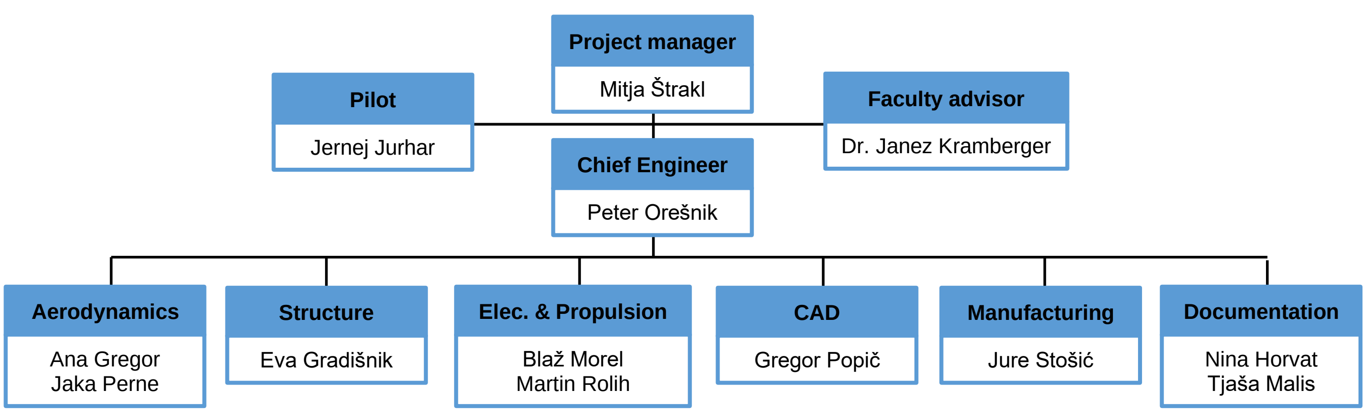


Figure 1: Organizational chart

task allocation and discussion, concerning workflow, major decisions and satisfactory progression according to our schedule. Each department has its own leader, who is responsible for communicating and updating our project leader about the completion of each task and ensuring a safe work environment in each workstation, with emphasis on the quality of their work. Our pilot was chosen, according to his background in flight aviation and simulation training. Figure 1 shows team's structure. For each department there are specific skills and responsibilities required for every member. Not to be cast aside, leadership of our team also holds responsibilities. Figure 3 shows responsibilities of our teams' leadership. Shown below are the leadership position's duties and skills required. All team members are included in various aircraft manufacturing processes in order to complete the aircraft as quickly as possible.

Table 1: Department sub-teams responsibilities and skillsets

Department	Responsibilities	Required Skillset
Aerodynamics	Shaping, sizing aerodynamic bodies and surfaces. Aerodynamic analysis to ensure efficiency, stability and aircraft control.	Knowledge of aerodynamics, stability and control. Proficiency in aerodynamic simulation & analysis software.
Structure	Airframe construction, selection of materials and manufacturing procedures. Structural analyses and A/C component testing.	Proficiency of non-destructive testing methods. Knowledge of metallurgy. Knowledge in statics and stress calculation.
Electronics & Propulsion	Design of radio control, transmitter signaling. Connectivity of onboard controls. Propulsion sizing and performance analysis.	Knowledge of signaling and harmonic oscillations. Knowledge of electronics, wiring skill. Knowledge of propulsion systems.
Computer-Aided Design	Design of molds, wing, tail, landing gear, etc.	Proficiency in Computer-Aided Design and structural analysis software.
Manufacturing	Electrical powering, wiring, telemetry for data logging. Creation of molds, wing, tail, landing gear, etc.	Knowledge of different material properties. Knowledge of electronics, engineering. Manufacturing skill and processing of different materials.
Documentation	Handling of general administrative work, sponsorships, budgeting and other documentation. Assistance to other teammates in manufacturing of the aircraft.	Proficiency in secretary work and organizational skill. Proficiency in publishing on media networks, video end photo editing software.
Project Lead / Chief Engineer	Allocation of tasks, managing meetings, determining workflow. Management of departments, overseeing quality of work	Proficiency in management and team lead. Organizational and planning skills. Quality management and control experience.

2.2 Budget

The size of the aircraft has a big influence on the total cost of the project. Expenses for the materials and manufacturing of the aircraft were estimated using previous seasons' expense figures and results of a design parameters study. All funds for materials and components are procured from local sponsors. The team's confirmed 2023 DBF budget is $3.500, and it is to be used for materials and components. The team's focus is on effective use and redistribution of the budget. Additional machining costs will be covered by the University of Maribor. Transportation, accommodation and allowance costs are based on trip offers from a local travel agency and will be covered by the State Student Fund, which grants $1.190 (1,200€) per participant. The total estimated costs for manufacturing materials, electronics and travel and accommodation for the team are shown in Table 2.

Table 2: Estimated budget:

Manufacturing materials	Number	Cost [1 pc]	Cost
Balsa	5	$ 12,00	$ 60,00
Plywood sheet			
Styrofoam	20	$ 10,00	$ 200,00
XPS Foam sheet			
3D-printing ABS Filament	4	$ 30,00	$ 120,00
Carbon fiber rod	5	$ 65,00	$ 325,00
MonoKote roll	3	$ 40,00	$ 120,00
Fiberglass			$ 300,00
Resin			
Adhesives			$ 60,00
Bolts			
Nuts			
		TOTAL	$ 1.185,00

Electronics	Number	Cost [1 pc]	Cost
Electric motor	2	$ 150,00	$ 300,00
ESC	2	$ 200,00	$ 400,00
Transmitter	1	$ 200,00	$ 200,00
Receiver			
Main battery pack	10	$ 30,00	$ 300,00
Servomotor	20	$ 4,00	$ 80,00
		TOTAL	$ 1.280,00

Travel and Accommodation	Cost [1 pc]	Cost
Flight tickets (12 persons)	$ 700,00	$ 8.400,00
Rent a car (10 days)	$ 120,00	$ 1.200,00
Fuel (10 days)		$ 500,00
Lodging (10 days)		$ 5.000,00
Meals (12 persons, 10 days)		$ 1.000,00
	TOTAL	$ 16.100,00

2.3 Major Milestone Chart

After the release of the competition rules, a Gantt chart (Fig. 2) was made, to set project deadlines to ensure the desired progress. The progress is recorded in the chart, and it will be presented thoroughly in the Design Report.

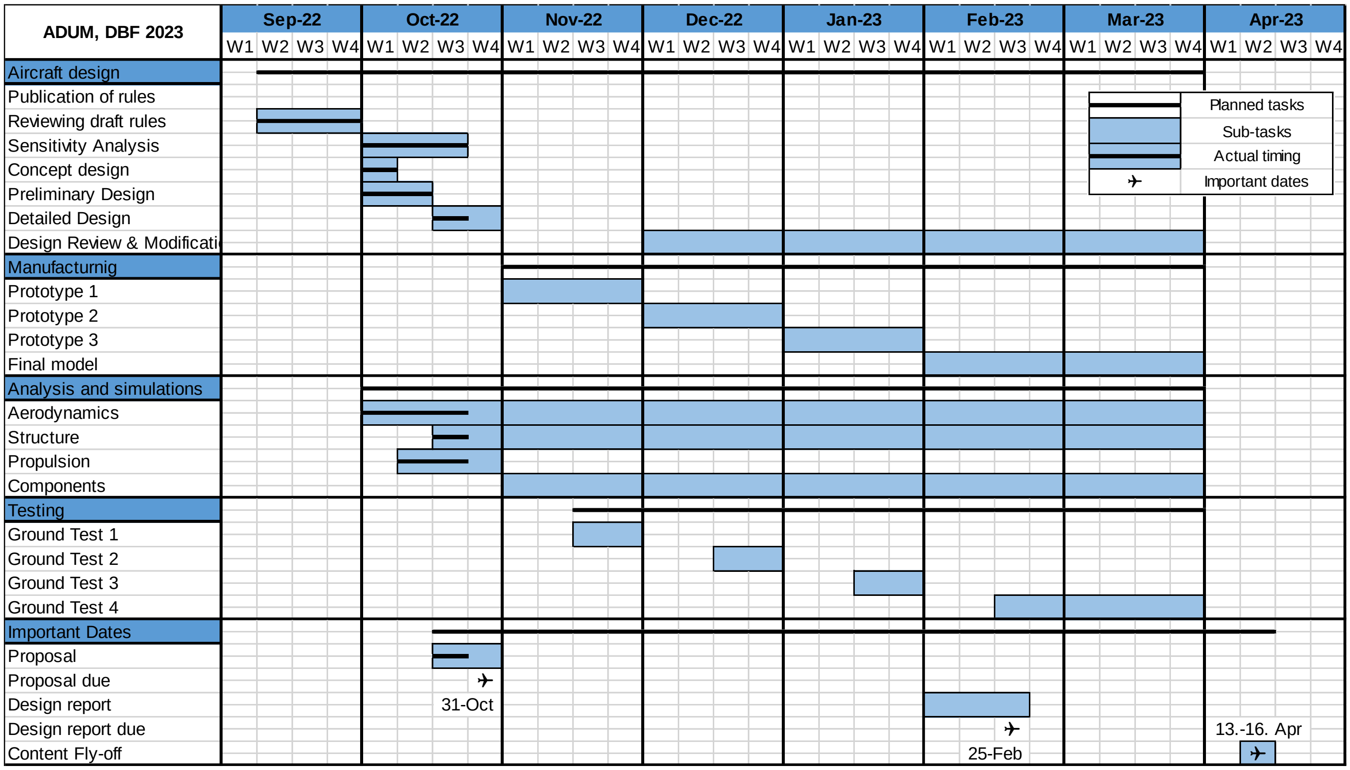


Figure 2: Project plan Gantt chart, with milestones

3 Conceptual Design Approach

3.1 *Mission requirements*

The objective for this year is to design and build an aircraft to carry a heavy payload and an externally mounted antenna. Considering those objects, initial sub-system requirements are defined, which serve as basic guidelines for the aircraft configuration selection and the preliminary design.

Table 3: Mission objectives, score and subsystem requirements

Mission	Payload	Mission objective	Time	Score	Sub-system requirements
M1	None	Complete 3 laps	5 min	$M1 = 1$	• Demonstrated robustness and reliability
M2	Electronic package	Maximize laps flown in time window	10 min	$M2 = 1 + \frac{(W_p \cdot N_{LAPS})}{(W_p \cdot N_{LAPS})_{\text{MAX}}}$	• Minimize drag at the mission cruise speed • Maximize structural resistance at given empty weight, additionally reinforce the payload carrier • Maximize lift at T/O speed, to ensure take-off in less than 60 ft
M3	Antenna	Minimize time required t_R for 3 laps	5 min	$M3 = 2 + \frac{(L_A/t_R)}{(L_A/t_R)_{\text{MAX}}}$	
GM	Max Payload (AUW)	Apply test weights up to maximal load W_{TEST}	10 min	$\text{GM} = \frac{(W_{TEST}/AUW)}{(W_{TEST}/AUW)_{MAX}}$	• Maximize wing load resistance • Ensure even load distribution, to reduce stress on the wing tips

3.2 *Score analysis and sensitivity*

The overall flight mission score consists of four individual mission scores, three of which are the subject of the present optimization problem. Those are Mission 2 (M2), Mission 3 (M3) and Ground Mission (GM). After analyzing each missions requirements, two significant design parameters were identified – payload weight W_p and antenna length L_A. Payload weight predominantely affects the expected performance in missions M2 and GM, with an inverse effect between the two as indicated in Fig. 3. For M2, increasing the W_p increases the mission score, suggesting that the aerodynamic penaly of the increased AUW is outperformed by the benefit of the increased W_p. Based on the preliminary aricraft sizing and aerodynamic analysis, it was established that increasing the W_p can even have a favourable effect on the aerodynamic performance as it increases the best glide speed. The extent of the W_p increase is however limited by the energy available in the battery, as

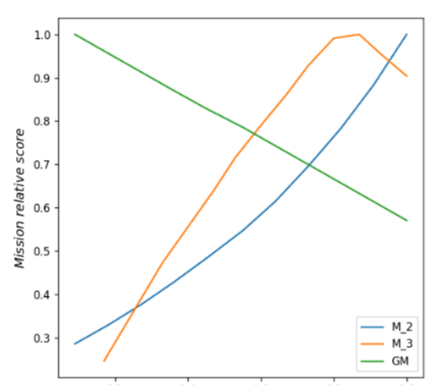


Figure 3: Individual mission score sensitivity

the power required to sustain flight at such conditions should not lead to premature battery drain. As far as the GM is concerned, increasing the W_p (and with that the AUW) reduces the mission score, asumming that the design structural load margin is kept the same. Nevertheless, it has been demonstrated that the benefit in M2 due to increased W_p outweighs the penalty in GM, meaning that the W_p should be optimized for M2. In mission M3, the objective for optimization is the antenna length L_A. Preliminary drag calculations show that the maximum structural cruising speed V_{NO} is decreasing with the factor $1/L_A$, due to bending moment acting on the antenna. The score in M3 is a tradeoff between L_A and mission time. Additionally, with increasing L_A, a linear speed penalty has been added to V_{NO}, due to the stability concerns. An optimization problem-maximizing the overall score, has been peformed (Fig 4), which estimates the optimal W_p of around 60% AUW and the optimal L_A of around 85% $L_{A,max}$.

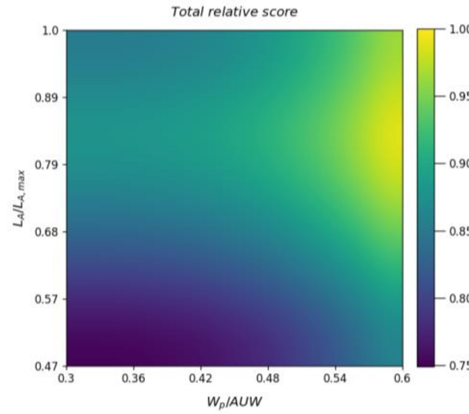


Figure 4: Optimized total score

3.3 Preliminary design

Concluded from the sensitivity analysis, a low drag, high structural resistance and a positive static and dynamic stability are the key design objects. As a result, a high-wing monoplane with tricycle landing gear configuration is selected (Fig. 5), as a trade-off between drag, structural resistance and ease of manufacturing. The initial wing design proposes a tapered wing with 5.3ft span, surface area of 4.3 sqft and an aspect ratio of 6. Basic design is proposing CLARK-Y airfoil, due to its favorable lift/drag relationship, while a further optimization via the CFD tools is pending. Due to the box size limitation, a bi-section fuselage with length of 4 ft is proposed, with empennage integrated into its rear section. Empennage dimensions and moment arms are optimized within the distance constraining to ensure positive static and dynamic stability, resulting in the horizontal tail-plane span of 1.5ft and height of the vertical tail-plane of 1 ft. Given the gross airplane size, a single front mounted electric-motor propulsion is selected with maximum power of 2kW. The energy requirements of the propulsion system are supported by the 6S 4500mAh lithium (LiPo) battery, which falls just under the 100 Wh energy storage limit. For the structure and propulsion of the presented aircraft, the predicted basic empty weight is 5.95 lbs. To allow for at least 7lbs payload, the design MTOW is 14 lbs (with small margin for an additional load). According to the preliminary drag and lift calculations, such a configuration results in stall speed of 33 KTAS, best glide speed of 50 KTAS and a maximum level-flight speed of 80 KTAS. Payload carrier is positioned approximately at the CG point, so that a flight configuration with or without payload can reach the design CG envelope, which is at 32-36% MAC according to preliminary calculations. Antenna mount is integrated in each winglet, which is bolted onto the wing. Threaded inserts in the wing are reinforced all the way to the main spar, to enable the ground test fixture to be attached to the same structure, thus reducing the mass of installing additional mounts.

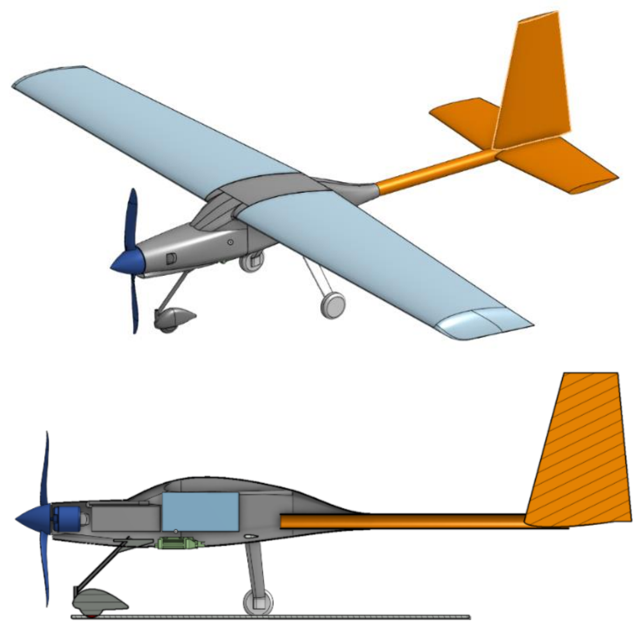


Figure 5: Preliminary aircraft model

4 Manufacturing plan

Manufacturing flowchart is illustrated in Fig. 6 and consists of several design and analyses stages, manufacturing and testing. This is an iterative process, where test results are evaluated, failures analyzed and improvement potentials defined. They are then returned back into the design loop trough the feedback stage, where design is updated accordingly and the process then repeats. As determined in the preliminary design guidelines, this year the manufacturing will be enhanced employing the additive manufacturing technologies (3D print). This will mainly be applied for front fuselage sections. As the technology allows for producing complex-shaped parts, the aerodynamic efficiency (low drag) objective will be prioritized in the fuselage design. Rear fuselage section is produced from a carbon tube at the end of which an empennage is mounted. Front and rear fuselage sections are

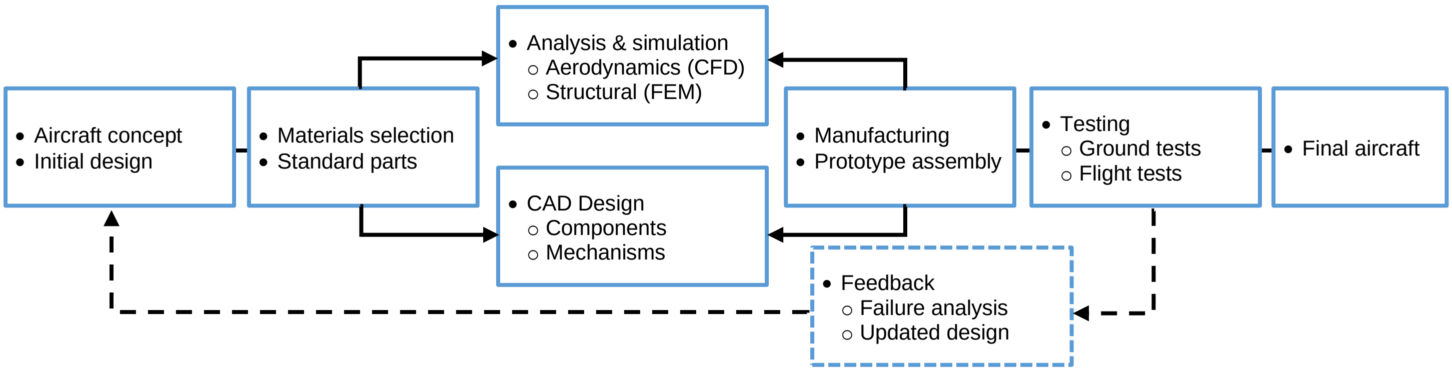


Figure 6: Manufacturing flowchart

assembled by the compressible joint and integrated in the front fuselage section. Critical components will be reinforced with carbon fibers, to ensure that structural resistance requirements are met. The main wing halves employ a sandwich construction with a foam core and carbon fiber shell. Carbon tube will be used as a main wing spar and to connect the two halves and the fuselage.

5 Test plan

The test plan schedule is given in Table 4 and proposes two main phases, namely ground testing and flight testing. The ground tests will start early in the design phase, to identify faults as soon as possible and reduce time and design efforts, required for their mitigation. Static and dynamic thrust and energy consumption will be measured including stress testing of the electrical components, to ensure their durability and reliability. Wing load testing will be performed thorough the design, to improve load resistance to the greatest extent. Fuselage sections will also be stress tested, to ensure that the deformations are within tolerance for conducting all flight missions. Flight testing, which will take place at an airport in Murska Sobota, will begin after the first prototype is built. First set of flights will determine aircraft's performance, stability and airframe capabilities. Second set of flights will determine the take-off distance, stall speed, best glide speed, and maximum level flight speed dependency on the TOW. Third set of flights will determine the propulsion characteristics in flight, i.e. energy consumption at different cruising speeds. After that, the endurance will be analyzed using different payload weights and throttle settings, to optimize the throttle management for the endurance flight.

Table 4: Test plan

Phase		Test	Objective	Deadline
Ground tests	GT1	Static thrust	Measure thrust, current and voltage specifications throughout the throttle curve and for different propellers	4.Nov
	GT2	Dynamic thrust	Install the thrust test bench on the vehicle. Measure thrust, current and voltage specifications throughout the throttle curve at different speeds.	18.Nov
	GT3	Wing load resistance	Mount the wings at the tips. Install the test weights until structure damage. Analyze the damage, improve the structure.	2.Dec
	GT4	Landing gear	Install the gear on the fuselage. Apply weight up to MTOW. Drop the fuselage from 2 ft.	16.Dec
Flight tests	FT1	First flight test	Perform a normal take off, climb, traffic pattern, land. Debrief, analyze static stability.	30.Dec
	FT2	Performance and stability flight	Gain altitude, perform stability testing: Longitudinal stability: Pitch moments, 3211 maneuvers. Lateral stability: Steady sideslip. Lateral stability: Rudder response.	13.Jan
	FT3	Take off performance, Speed tests	Perform multiple flights at various TOW. Measure TO distance, stall speed, best glide speed, max speed.	27.Jan
	FT4	Cruise performance	Perform multiple flights at various TOW. Measure speed and energy consumption characteristics.	10. Feb
	FT5	Endurance test	Using the results from FT4 and FT5 select optimal TOW. Perform 10 min endurance flight, optimize throttle management.	21. Feb