Cairo University

AIAA 2018-19 DBF Competition Proposal

1. Executive Summary

This proposal represents Cairo University, Unmanned aerial systems Development Center (UDC), team's planned approach for the design, analysis, manufacturing, and testing processes for the 2019 AIAA Student DBF Competition.

Our objectives for this year is to develop an unmanned radio controlled multi-purpose aircraft to support carrier operations. The aircraft with a minimum wingspan of 4 feet should be capable of automatically folding its lifting surfaces in order to roll through a 3 feet wide box. The aircraft would also carry a minimum of four attacking stores that are remotely detached to simulate an attacking mission. In addition, a rotating radome would be mounted on top of the aircraft to simulate a reconnaissance mission.

With this year being the second participation in a row for some of our team members, their accumulated knowledge and experiences from the past year is expected to be of great use to all new team members, and would help in avoiding last year's mistakes.

In order to better understand and analyze the scoring system we performed a score sensitivity analysis, and concluded that apart from the design report, the number of successful laps in the third mission is the most affecting parameter, and hence our whole design process will be focusing on maximizing this particular parameter. Accordingly, we came up with our design for this year which is a single-motor, single-boom, conventional aircraft with four bar linkage foldable self-locking wing, and a large payload fraction, designed to carry 8 attacking stores with an electrical servoless releaser.

2. Management Summary

2.1 Organization Description

Our team consists of a faculty advisor, chief engineer and 11 undergraduate students from different academic years, some of which have participated in last year's competition and others with no experience other than participating in the local DBF competition, which is organized annually by the UDC lab team. This team dynamic ensures a continuous flow of experience and knowledge among team members and hence ensures the continuation and development of the team.

The faculty advisor monitors the progress of the team, and is always there to provide the necessary guidance and consultations. The chief engineer is consulted by the team when making influential decisions. The team leader is an elected team member who manages the team, assigns tasks for each sub-team and ensures that everything is going according to the schedule. The rest of the team is divided into seven parallel sub-teams. A weekly meeting is held to discuss progress, opinions, and problems, and accordingly take decisions, which are often agreed upon by all team members, however, in case of conflicts, the team leader discusses the situation with the chief engineer in order to take the final decision. Table 2.1 discusses the roles and the required skill sets for each sub-team.

Sub-teams	Sub-teams Roles	Required Skill Sets
Aerodynamics	• Aircraft sizing, stability, and performance based on aerodynamic calculations.	• Aerodynamics concepts grasp. • Use of CFD & X-foil based software.
Structure and CAD	• Designing and modelling the aircraft structure. • Performing various structural tests and simulations.	• Knowledge of structural analysis. • Handling CAD and FEA software.

Propulsion	• Performing tests and calculations upon which motors and batteries will be selected.	• Fair knowledge about propulsion systems.
Manufacturing	• Machining the required parts and assembling the aircraft.	• Assembly techniques. • Handling CNC machines.
Technical Writing	• Writing / formatting the proposal and design report.	• Writing skills. • Technical skills.
Media	• Running the team's social media channels. • Producing well-designed illustrations.	• The ability to use various design and photo editing software.
Treasury	• Responsible for fundraising , budget planning and handling purchases	• Experience of financial control and budgeting.

Table 2.1: Sub-teams Roles and Required Skill Sets

2.2 Organization Chart

Figure 2.2 sums up the hierarchical structure of the team. Each member can suggest ideas and state opinions in any subject, and all team members work together and help each other to achieve the objective of the team.

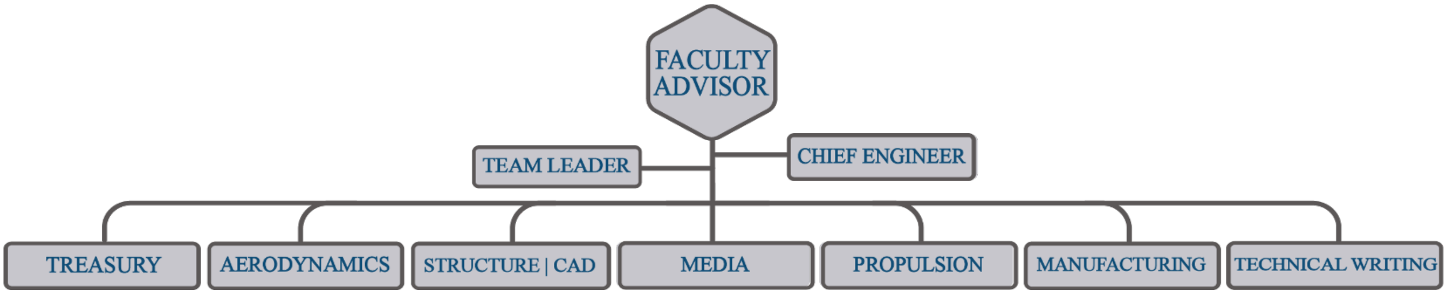


Figure 2.2: Team structure

2.3 Schedule | Major Milestone Chart

A Gantt chart was organized to streamline the workload and to ensure that the goals will be achieved on time.

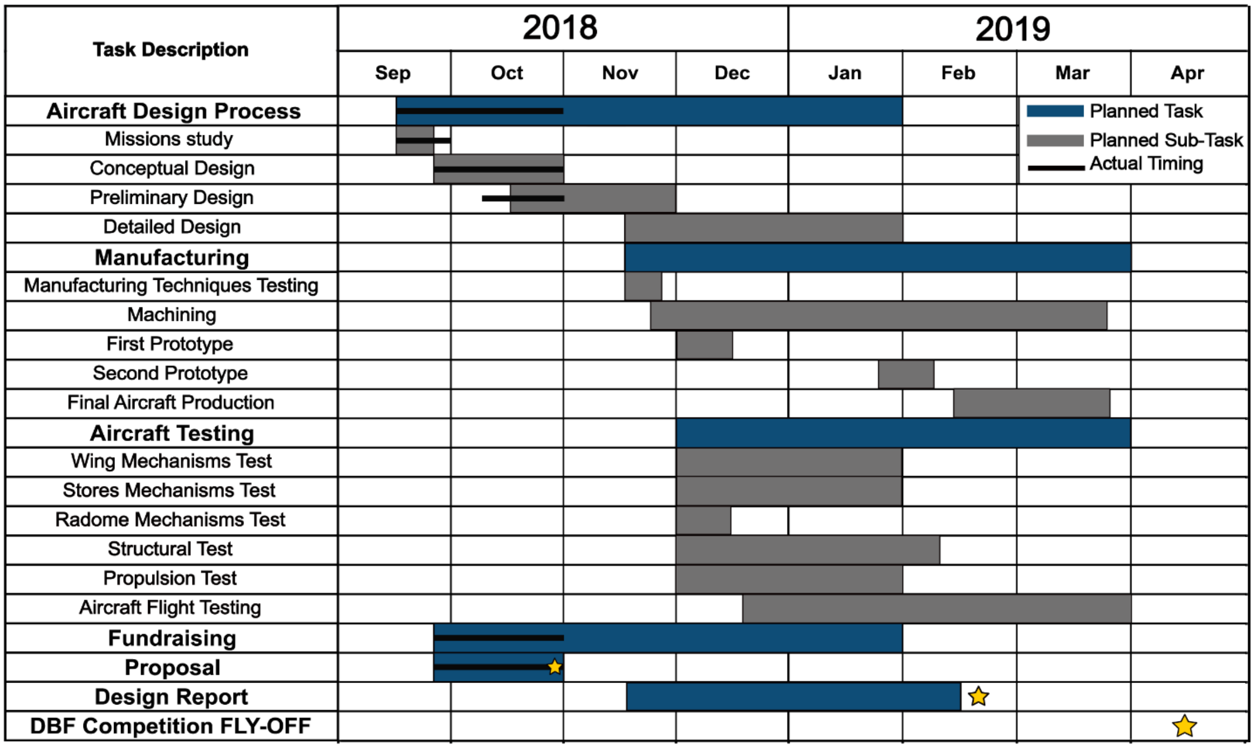


Figure 2.3: Gantt chart

2.4 Budget

After considering last year’s financial data, and researching this year’s expected expenses, we estimated the following budget.

	Quantity	Item	Cost (USD)	Total Cost (USD)
Concerning The Aircraft	**3**	Brushless Motor | Propeller	$180	**$1285**
	3	E.S.C	$25/unit	
	20	Servo Motor	$5/unit	
	30	Main Battery Cells	$4/unit	
	1	Transmitter | Receiver	$300	
	-	Carbon Fiber Rods	$110	
	-	Balsa | Plywood | Foam | Fibers	$400	
Traveling and shipping	**6 Members**	Transportation	$900/member	**$7850**
	6 Members	Lodging	$350/member	
	-	Aircraft Packaging | Shipping	$350	

Table 2.4: Estimated budget

Our main source of fund is Cairo University funding program and the Egyptian academy of scientific research and technology. In addition, the treasury team is pursuing new and different funding strategy for this year by preparing several sponsorship proposals and presentations to various companies and national organizations that we target.

Most of the required machines are already available in the UDC lab. Regarding the aircraft shipping to the competition location, we are planning to design the aircraft so that it can be dis-assembled to minimize the storage needed.

3. Conceptual Design Approach

3.1 Analysis of the Mission Requirements

As stated by this year’s rules, the competition objective for this year is to develop a multi-purpose aircraft to support carrier operations. In addition to the flight missions’ requirements, there are some general rules and restrictions regarding the aircraft design and performance this year. Table 3.1 will illustrate the design requirements for this year’s competition and their decomposition into sub-teams requirements.

Missions		Requirements	Sub-teams Requirements
Ground Mission		• Installing/Removing the rotating radome and attacking stores in the short time. • Remotely folding surfaces with self-locking mechanisms.	• Research and test different wing folding and mechanical locking mechanisms. • Ensure mechanisms simplicity, to speed up the process.
Flight Missions	Mission 1	• The unloaded aircraft must complete 3 laps in 5 minutes.	• Minimizing the aircraft stall speed to be capable of taking off from the ramp. • Manufacturing a visually clear radome by coloring it with different colors. • Designing a mechanism that ensures the drop of a single attacking store at a time. • Ensuring auto trimming after each store drop to balance the CG variation.
	Mission 2	• The aircraft loaded with the rotating radome must complete 3 laps in 5 minutes.	
	Mission 3	• The aircraft loaded with the attacking stores has a 10 minutes flight window in order to drop the stores, one in each lap.	

Table 3.1: Mission Requirements Analysis

3.2 Sensitivity Analysis of Design Parameters

Knowing how vital this step is, we analyzed the scoring system to decide the sensitivity of the total score to the variation of each design parameter using two different methods.

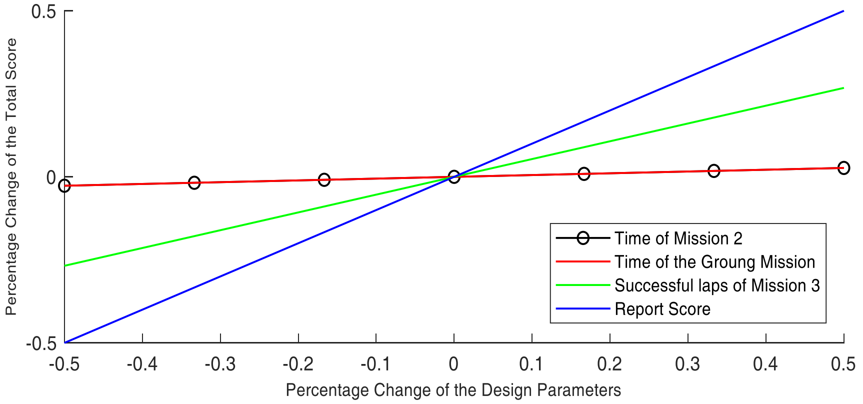


Figure 3.2.1: Sensitivity Analysis Plot

$\frac{report}{total\ score} \cdot \frac{\partial(report)}{\partial(total\ score)}$	1
$\frac{M3\ laps}{total\ score} \cdot \frac{\partial(M3\ laps)}{\partial(total\ score)}$	0.5357
$\frac{GM\ time}{total\ score} \cdot \frac{\partial(GM\ time)}{\partial(total\ score)}$	0.05357
$\frac{M2\ time}{total\ score} \cdot \frac{\partial(M2\ time)}{\partial(total\ score)}$	0.05357

Table 3.2.2: Fractional Sensitivities

Starting from a well chosen nominal values for the parameters, and using MATLAB, we plotted the percentage change of each scoring parameter along with the percentage change of the total score in figure 3.2.1.

Using the partial differentiation method (linear sensitivity analysis), with the same nominal values, we achieved the following tabulated fractional sensitivity for each parameter in table 3.2.2.

Both methods showed that the scoring equation is most sensitive to the report score, followed by the successful laps of mission 3. These results well be used through out the design process to dictate the design parameters in order to maximize the total score.

3.3 Preliminary Design | Sizing Results

After conducting the sensitivity analysis, the team main focus was reducing the empty weight to maximize the number of attacking stores. Hence, we decided to carry 8 attacking stores for the third mission, which defines our estimated maximum take-off weight to be $6.18\ lbs$. In order to meet the ramp take-off distance requirement our calculations showed that a wing with a $C_{L_{max}}$ of 1.3 and a wing surface area $4.31\ ft^2$ is required to achieve a stall speed of $35.4\ ft/sec$. For our first prototype, we chose our wing aspect ratio to be 5, producing a $4.6\ ft$ wingspan and a $0.92\ ft$ chord, which will create $6.38\ lb$ lift force that requires $8.2\ ft$ to take-off. Proceeding to the aircraft longitudinal stability calculations, we designed for a static margin of 0.14 and a tail arm of $2.15\ ft$, which yielded the tail sizing to be of a $1.57\ ft$ span and a $0.64\ ft$ mean chord. The following figures presents the chosen aircraft configuration and folding mechanism, which is a spherical four bar linkage mechanism.

Figure 3.3.1: The Unfolded Aircraft

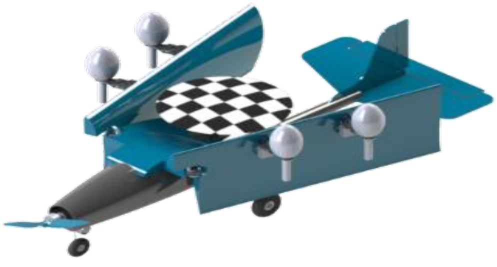


Figure 3.3.2: The Aircraft in the Stowed Configuration

We researched different wing-folding mechanisms but decided to use the spherical four-bar linkage mechanism (with some modifications) for the first prototype, as shown in figure 3.3.3. This mechanism allows for the backward folding of the wing by simply rotating the main bar using a simple servomotor.

Regarding the self-locking mechanism, we are planning to use a spring loaded lock for the first prototype. As for the releasing mechanism, we are planning to attach the stores to an electrical servoless releaser, which will enable us to achieve a sequential stores drop.

Figure 3.3.3: Folding Mechanism

4. Manufacturing Plan

Our preliminary manufacturing flow is plotted in figure 4; we plan to take feedback from testing the manufactured components in order to optimize them in the upcoming prototypes.

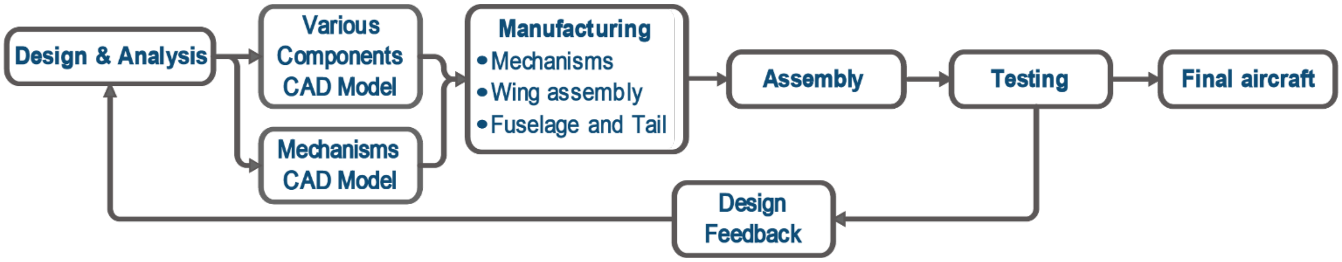


Figure 4: Manufacturing Plan Flowchart

The manufacturing materials would be decided based on the selections of the structural design team, taking into consideration the team's easily accessible materials and technologies, which are a CNC milling machine, a laser cutting machine, a CNC hotwire foam cutter machine and a 3D printer.

For the first prototype, we will manufacture the wing using a balsa build up method, while the fuselage, and the tail assembly will be built using plywood and balsa, all the wooden parts will be cut using the CNC laser cutter. The main landing gear will be manufactured from thin aluminum strips. More complex sub-assemblies such as the wing folding mechanism, joints and the attacking stores mechanism will be 3D printed. Critical parts such as the boom, the wing spars and the nose will be made out of carbon fiber to ensure their strength.

5. Test Planning

Using a static thrust stand, several combinations of motors, batteries, and propellers will be tested to get the best combination that matches our static thrust requirements, battery discharge rate, capacity and endurance. Furthermore, a wing tip test using 1.5x of the airplane's maximum takeoff weight will be conducted to ensure the stiffness of the self-locking mechanism and the reliability of the structure. We will also test the wing folding mechanism for efficiency and reliability. In addition, the landing gear will undergo a drop test to ensure its endurance of impact loads, as well as a taxing test to verify the steering controllability on the takeoff ramp. The assembly crew team members will undergo a simulated ground mission to speed up the assembly process. After assembly, a balance test will be made to check whether the center of gravity is in the allowable range.

After testing the subsystems, the aircraft will be subjected to real flight tests mimicking the missions of the competition to check the overall performance of the aircraft, collect real-time data and pilot's feedback. The trimming of the aircraft using the control surfaces will be tested after dropping each attacking store to balance the effect of the variation of CG position. The results of the flight tests will be used to modify and enhance our upcoming prototypes.

Advisors: Dr. Jeff Jepson, Lance Bays

2018-2019 AIAA Design, Build, Fly Proposal

Proteus

Executive Summary

This is the University of Arizona's proposal for the 2018-2019 AIAA Design Build Fly competition and includes plans for the design, testing, and analysis deemed necessary for successful completion of all requirements. The name "Proteus", the Greek God of the River known for versatility and an ability to adapt, has been chosen for our program.

This year, the purpose of the competition is to create a readily deployable, remote-controlled, electric powered unmanned aircraft. Aircraft capabilities shall be demonstrated during four missions and a technical inspection at the 2019 AIAA DBF Fly-Off.

Reasoning for our chosen management structure, schedule, and budget are discussed in subsequent sections. Additionally, logic leading to our preliminary conceptual design are discussed and later related to our manufacturing and test plans.

Analysis of the competition scoring system revealed mission 3 to have the most significant contribution to total score, thus endurance and payload capacity were chosen as focal points. Following analysis relating key design parameters, the team chose to pursue a blended wing/body design to achieve a low takeoff velocity at high aerodynamic efficiency. A taildragger configuration was chosen to reduce ground roll, and a twin-engine configuration was implemented to eliminate yawing on takeoff and increase the effect of prop-downwash on coefficient of lift.

Management Summary

Design of our organization's structure, Figure 1, was driven by the identified interaction between aerodynamics, structures, and propulsion. These relationships are shown in Figure 3. Reasons for focusing on these design parameters are discussed in the conceptual design approach section. The responsibilities associated with each role are as follows:

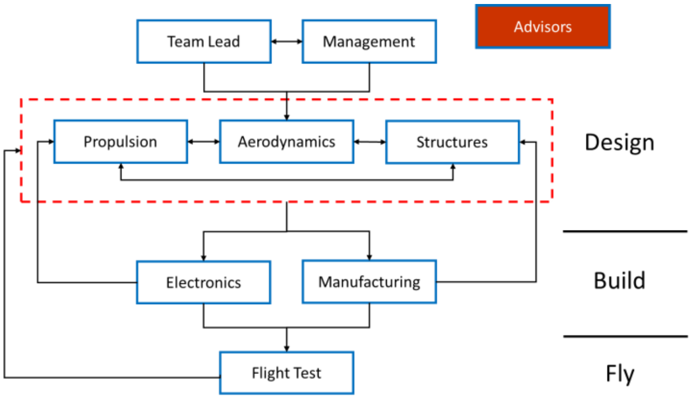


Figure 1 Proteus Team Structure

Team Lead: Actively engage with all sub-teams, providing input, resolving disputes, and approving final decisions throughout the project.

Management: Provide logistical support to ensure the team remains on or ahead of schedule (Figure 2) and under budget (Table 1).

Propulsion: Validate power system requirements. Select a motor/battery configuration based on comparisons between static thrust experiments and minimum thrust loading requirements.

Aerodynamics: Conduct analyses and design studies to size surfaces, validate aircraft stability, and identify relationships between design choices (i.e. relating effects of prop wash on coefficient of lift).

Structures: Conduct trade studies to select structural components meeting wing loading requirements driven by maximum coefficient of lift provided by the aerodynamics team.

Electronics: Select and safely integrate supporting equipment for our propulsion system. Design and implement solutions to effectively drop stores and reliably rotate the radome.

Manufacturing: Produce required parts to implement designs passed from the aerodynamics, propulsion, and/or structures group. Build quality shall be motivated by safety and wing loading requirements from the structures group.

Flight Test: Execute the flight test plans as specified in the test planning section to validate design and gain familiarity with mission requirements. The team shall include a safety officer to enforce safe decisions during tests.

The team's chosen schedule is provided in Figure 2 and includes white lines through respective segments indicating current progress and actual start times.

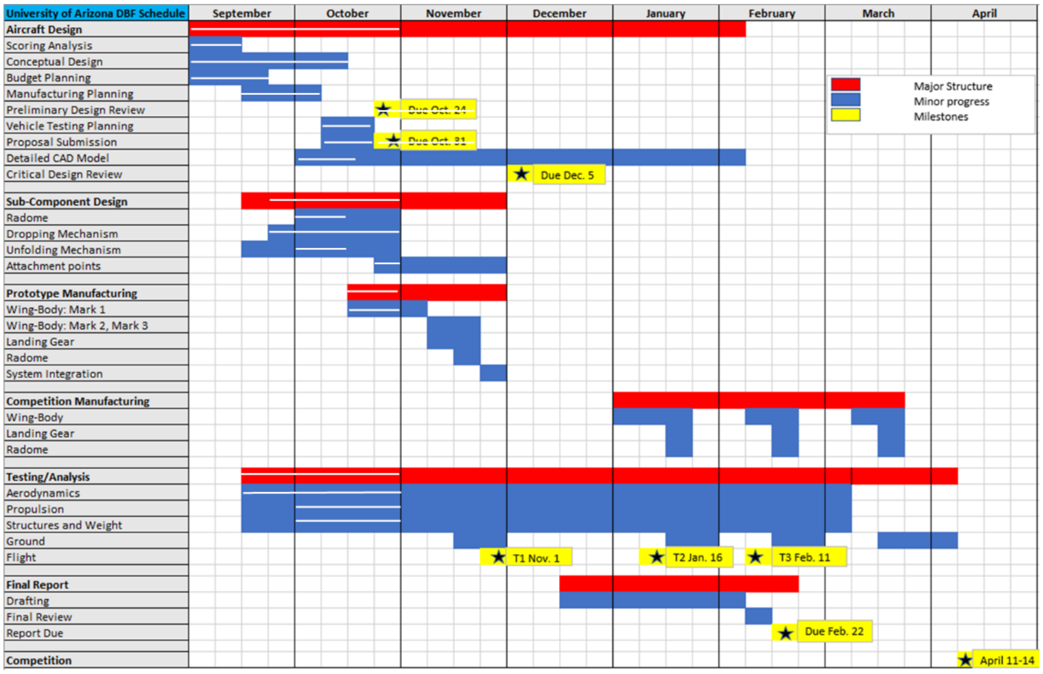


Figure 2 Gantt Chart

A foam prototype of our final conceptual design has been manufactured. It will be flown prior to the first scheduled flight test.

Table 1 Proteus Budget

Category	Item Name	Cost
Propulsion	2 Motors (3x)	$300
	ESC (3x)	$135
	Batteries	$60
	2 CR Props (3x)	$60
Structures	Balsa Wood	$100
	Monokote	$30
	Epoxy	$20
	Landing Gear	$15
	Tools/Fasteners	$10
	1 Kg ABS Spool	$25
	Foam	$20
Electronics	Servos	$60
	Pushrods	$30
	Transmitter	$100
	Receiver	$20
	Total	$985

Project budget is included in Table 1. Funding shall be primarily obtained from the Tucson AIAA branch, the University of Arizona, specifically the College of Engineering, Engineering Student Council, Aerospace and Mechanical Engineering Department, and the student AIAA branch. Of note, because the competition is in Tucson, AZ, the team will not require separate travel funds.

Conceptual Design Approach

Conceptual design has been, and will continue being, driven by the unique balance required to successfully meet all mission requirements. High level mission requirements are provided as follows:

The aircraft shall:

- Have a wingspan of at least 4 feet
- Fit inside of a 2’ x 2’ x 3’ box
- Enter the flight ready configuration via transmitter input
- Takeoff along a 10-foot, 5-degree inclined ramp using only electric motors
- Pass 2.5 g wing loading test in the flight ready configuration
- Complete a ground mission demonstrating its readily deployable nature by installing necessary attachments within 5 minutes
- Complete a flight mission consisting of 3 laps flown without any payload within 5 minutes
- Have a tail hook on centerline
- Complete a flight mission consisting of 3 laps flown with the rotating radome payload attached, within 5 minutes
- Complete a flight mission consisting of 4 laps flown, dropping 1 store per lap from beneath the wings, within a 10-minute window

Early review of competition requirements revealed the takeoff requirement to be a significant challenge; therefore, the team pursued a design minimizing takeoff velocity by maximizing lifting surface area and coefficient of lift.

Further, a sensitivity of design parameters study, shown in Figure 3, was conducted and revealed maximum coefficient of lift, wing loading, and thrust loading to have the greatest impact on mission scoring. Results in Figure 3 were generated by varying one parameter while holding others constant to determine takeoff velocity and subsequent average velocity. Using the approximation for average velocity and the known lap distance, estimates for variations in mission scoring were produced.

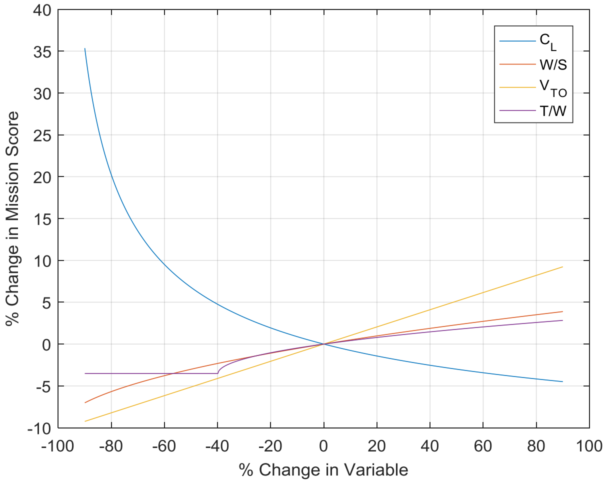


Figure 3 Sensitivity of Design Parameters

Further, Figure 4 was developed to demonstrate the relationship between our three critical design parameters.

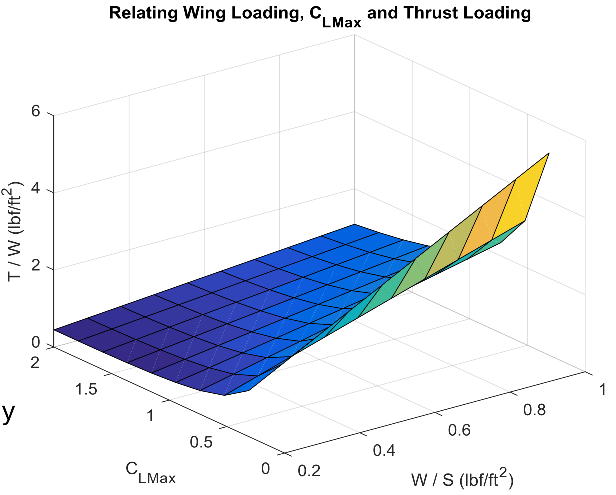


Figure 4 Relating Critical Design Parameters

Figure 4 demonstrates the relationships necessary to takeoff under the competition’s requirements for any aircraft (i.e. the results are independent of weight and wingspan). Ultimately, Figure 4 provides minimum design requirements with the dark blue region being the most optimized. These results will be used to facilitate the iterative design process. Results provided by the aerodynamics team for maximum coefficient of lift will drive minimum manufacturing and structural design requirements in terms of wing loading. Then, the propulsion team must validate that their motor selection provides the minimum thrust loading plus a factor of safety. Preliminary vehicle sizing, in inches, is provided in Figure 5.

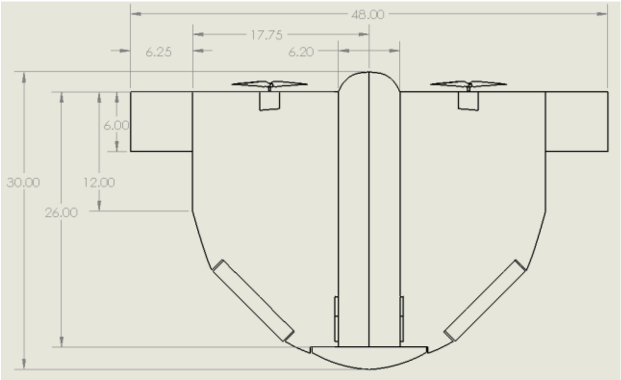


Figure 5 Preliminary Vehicle Sizing

The aircraft was designed to the minimum wingspan requirement, alleviating structural design challenges associated with the introduction of a more robust, sophisticated unfolding mechanism. The resulting conceptual design is shown in Figure 6.

A twin, counter-rotating propeller configuration was chosen to eliminate the yawing moment caused by a single propeller at high power settings and to maximize the potential for prop-downwash to increase the vehicle's coefficient of lift. Early design analysis in XFLR, on open source aerodynamic simulation tool, revealed a significant decrease in coefficient of lift due to induced drag effects on our low aspect ratio wing. These results were further validated through VORLAX, an open source Vortex Lattice program, and lifting line theory. For this reason, analyses will be done to identify the optimal propeller location for propeller vortices to cancel wingtip vortices. Contrary to typically flying wing designs, a straight leading edge was selected to maximize flow "seen" by the wing, helping keep the vehicle's takeoff velocity to a minimum. This design decision results in a relatively forward neutral point and thus, introduces the need for a center of gravity that is very close to the leading edge. Further, while many flying wings leverage their swept geometry to introduce elevons, we separated our elevator and ailerons, aiming to maximize pitch authority. Finally, a taildragger configuration was chosen to introduce an angle of attack on the ground, minimizing energy lost to rotation during ground roll.

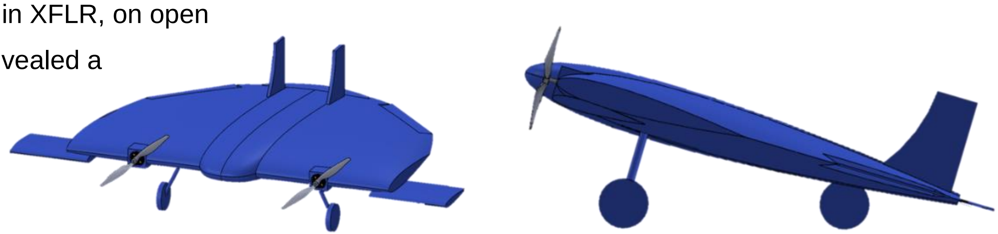


Figure 6 Conceptual Design

For the second flight mission, a radome will be attached at the aircraft's center line, specifically on the center of gravity. A prototype method for continuous radome rotation in which the potentiometer is removed from a standard servo motor has been developed and successfully demonstrated. For the third flight mission, at least four stores will be attached under the aircraft's wings. A 3-D printed mechanism providing the capability to drop two stores, one at a time, using one servo, has been created and successfully demonstrated.

Manufacturing Plan

The team's manufacturing flow is displayed in Figure 7. The aircraft will be primarily composed of balsa and Monokote. The shape of the blended wing-body requires three spars: one thick spar running along the leading edge, one spar running at ¼ chord, and two diagonal spars along the curved sections of the body which meet in a central area. There will be approximately 11 ribs, each a ¼ inch thick. The manufacturing team shall take advantage of readily available laser cutters to cut ribs and spanwise spars. Commercially available Monokote will form the skin of the aircraft.

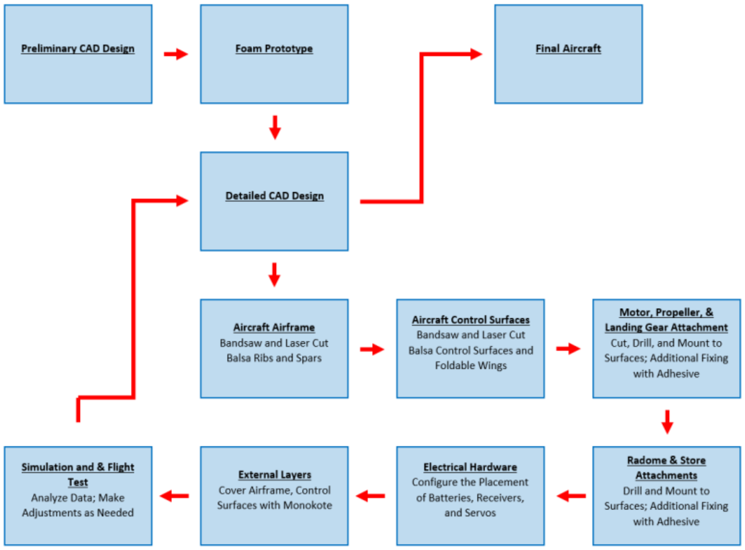


Figure 7 Manufacturing Flow

Test Planning

Ground testing shall include validation of our "unfolding" mechanism, wing tip testing, taxi testing, and radome rotation testing. Additionally, ground testing shall include practicing the ground mission to improve crew performance and identify areas for design improvement.

Three flight tests are planned and designed to incrementally check key design conditions and performance parameters. Dates for these flights are November 30th, January 16th, and February 11th. The first flight will consist of a general flight worthiness check; trim conditions will be set, and an approximate course run time will be obtained. During the second flight test, viability of the systems for missions two and three shall be checked. During the final test, all checks from the previous flights will be repeated, and mission run-throughs will be performed to obtain mission scores.

Adherence to requirements for sub-systems is confirmed through testing and specifically validated through analysis and/or inspection. Through inspection, test results are recorded via observation. Through analysis, test results are recorded via measurement and compared to predictions resulting from computations and simulations.

Table 2 Testing Plan

System	Sub-System	Testing Device	Validation Method	Test Description	Deadlines
Propulsion	Motor and Prop	Motor test stand	Analysis	Analyze static thrust and efficiency measurements for multiple configurations	Nov. 30, 2018
	Battery	Motor test stand	Analysis	Analyze voltage, current draw, and battery life measurements for multiple configurations	
Electronics	Flight Ready Condition	Transmitter	Inspection	Visually and physically confirm automated command to flight ready and locked position	Nov.16, 2018
	Store Dropping Mechanism	Transmitter	Inspection	Visually confirm solid attachment of mechanism and ability to drop one store at a time	
	Radome	Transmitter, Stopwatch	Analysis & Inspection	Visually confirm consistent rotation and calculate period of rotation using stopwatch	
	Control Surfaces	Transmitter	Inspection	Visually confirm proper deflections given transmitter input	
Structures	Center of Gravity	Finger placement, Scales	Analysis & Inspection	Physically confirm location using fingers and compute location using three scales	Nov. 30, 2018
	Folding Section	Bending Test	Analysis	Apply increasing loads to fixed demonstration folding section until failure	
	Wing Internal Structure	Bending Test	Analysis	Apply increasing loads to fixed wing with monokote until failure	
Flight	Takeoff Distance	Flight test	Analysis & Inspection	Visually confirm safe takeoff and paint wheels to compare actual ground roll to predicted	Feb 1st, 2019
	Speed	Stopwatch	Analysis	Use at least two stopwatches to confirm lap times and provide comparison to preditions	
	Stability	Pilot feedback	Analysis & Inspection	Compare pilot feedback and glide tests with XFLR5 and Vorlax simulations	
	Range	Flight test	Analysis	Complete flight test of 80% computed range to confirm battery life estimates	
	Endurance	Flight test	Analysis	Complete flight test of 80% computed endurance to confirm battery life estimates	

University of Southern California

2018-19 AIAA Design/Build/Fly Design Proposal

1.0 Executive Summary

The objective of the 2018-19 AIAA Design/Build/Fly (DBF) competition is to design a multi-purpose aircraft to support aircraft carrier operations. The aircraft must have a wingspan of at least 4 feet but still be able to roll through a space that is 3 feet wide and 2 feet tall, requiring mechanisms that remotely transition the aircraft from stowed to flight configuration and mechanically lock without assistance. Additionally, the nose to rear landing gear distance must be less than two feet; however, parts aft of the landing gear can extend further. The aircraft must also takeoff from a 10 foot, 5° inclined ramp while carrying a rotating radome and deploying attack stores in separate missions.

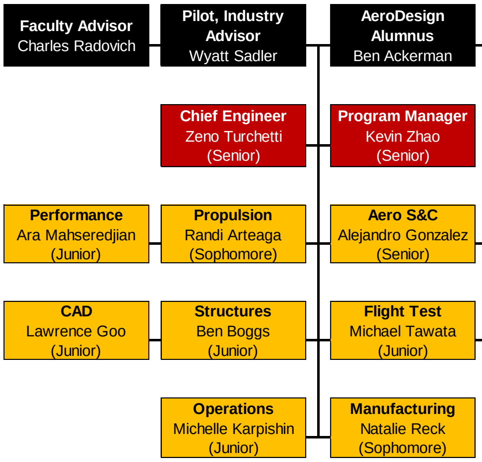
To achieve these objectives, the team must start with a detailed score sensitivity analysis to determine the most critical design parameters. This is followed by the conceptual and preliminary design for which component level items are 3D modeled, prototyped, and tested. Next, during the critical design, the entire aircraft is fabricated and flight tested to validate the design and refine the structure, aerodynamics, performance, and propulsion systems.

From preliminary analysis and design, the University of Southern California's AeroDesign Team chose a monoplane configuration with an 8 foot wingspan, H-tail, composite fairing, and a carbon-rod tail boom in order to maximize payload storage underneath the wing and fuselage while still adhering to spatial constraints. The monoplane utilizes a tricycle landing gear, which integrates onto the composite fairing. The designed aircraft can carry a rotating radome for M_2 and carry 13 attack stores that can deploy individually for M_3.

2.0 Management Summary

The 2018-19 USC AeroDesign Team consists of 35 students that participate on an extracurricular basis. Five members are seniors while the remainder are underclassmen. The team is entirely student-led but receives guidance from industry advisors, USC alumni, and faculty members at weekly meetings and design reviews.

Team Organization > The AeroDesign Team of USC employs a matrix structure of leadership, similar to the management hierarchy at most aerospace firms. Presented in Figure 1, team leaders (**red**) receive suggestions from team advisors (**black**) and coordinate the design effort among sub-team leaders (**gold**). The Chief Engineer and Program Manager divide tasks such that the Chief Engineer supervises design, build and test efforts while the Program Manager sets major milestones, maintains the master schedule, coordinates documentation efforts and coordinates with the Operations Manager to obtain funding and manage team logistics.



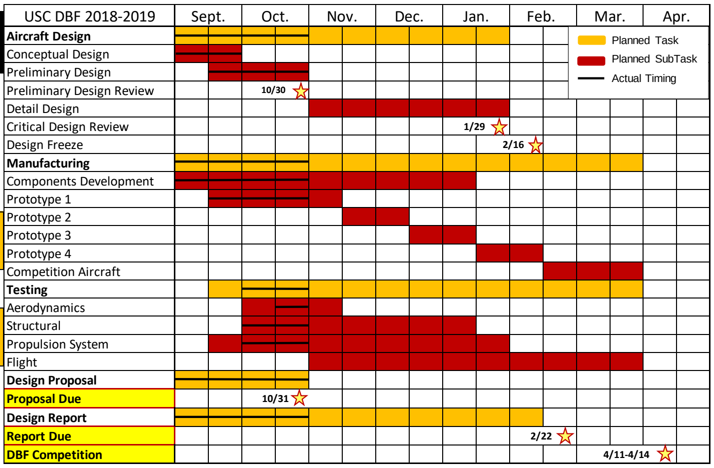


Figure 1: USC AeroDesign Team Organization

Figure 2: AeroDesign Team Milestone Chart

Schedule > The Program Manager maintains a Gantt chart with planned and actual schedule, shown in Figure 2. This schedule helps assess how long a task should take, determine required resources, and plan task dependencies. Note that the actual timing is not shown for future tasks.

Budget > Throughout the 30-year history of AeroDesign Team of USC, the team has maintained close relationships with industry sponsors who provide annual donations that allow the team to compete at a high level. The proposed budget for the 2018-19 competition consists of $6,800 for lab tools, $13,500 for material/component costs, and $500 for office supplies. Through the combined support of corporate sponsors, university funding resources, and individual contributions from alumni, the team has been able to meet all costs associated with the production of its competition aircraft. The team will be traveling to Tucson in vans rented through Enterprise Rent-A-Car and will be staying at Quality Inn Airport North. The expected travel and lodging expenses of $5,500 will be covered through university funds, allowing the team to bring all captains, primary contributors, and the aircraft to competition.

3.0 Conceptual Design Approach

During the conceptual design phase, the team analyzed the competition requirements and the scoring equation to set design parameters for the remainder of the competition year. Numerous aircraft configurations were evaluated in order to identify the highest scoring configuration. The final product of the conceptual design phase is the preliminary design presented in Figure 5.

Mission Requirements > The 2018-19 DBF competition consists of three flight missions and one ground mission. The plane for this year's contest is intended to simulate a multipurpose aircraft to support aircraft carrier operations. The mission descriptions and scoring are shown in Table 1.

Table 1: Mission scoring and descriptions for DBF 2019

Mission	Successful Mission Score	Flight Description
Delivery Mission	$M_1 = 1.0$ (Successful flight)	3 laps, no payload
Reconnaissance Mission	$M_2 = 1 + \frac{(T_{M2})_{BEST}}{(T_{M2})_{USC}}$	3 laps, rotating radome
Attack Mission	$M_3 = 2 + N_{scoring\ laps}$	10 minutes, dropping team specified number of attack stores (one per lap)
Ground Mission	$GM = \frac{(T_{GM})_{BEST}}{(T_{GM})_{USC}}$	Demonstrate remote transition and from stowed to self-locked flight configuration, install both payloads, then show rotation and deployment, respectively

Scoring Summary > The overall scoring equation for DBF 2019 is shown in Equation 1 with M_1, M_2, M_3, and GM defined in Table 1.

$$SCORE = Report\ Score * (M_1 + M_2 + M_3 + GM) \qquad \text{Equation 1}$$

Score Analysis > Initial score analysis, shown in Figure 3, indicated that the scoring equation was most sensitive to the number of scoring laps flown for M_3. By linking the increase in payload carried and laps flown with TOFL limitations, an aircraft with an 8-foot wingspan, carrying 13 attack stores for M_3, would yield the highest score.

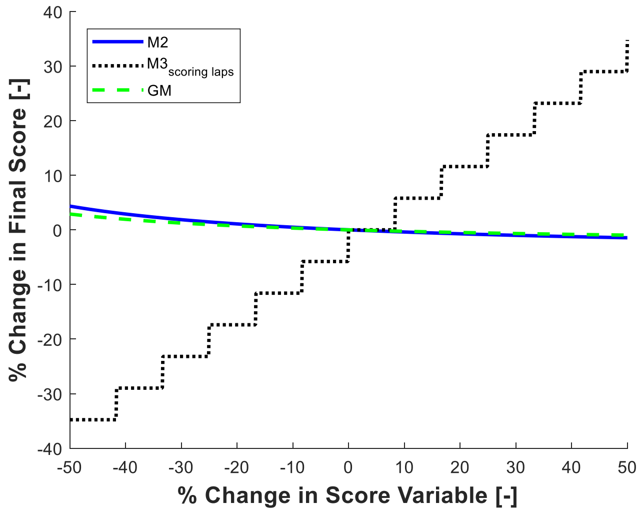


Figure 3: Preliminary Score Analysis

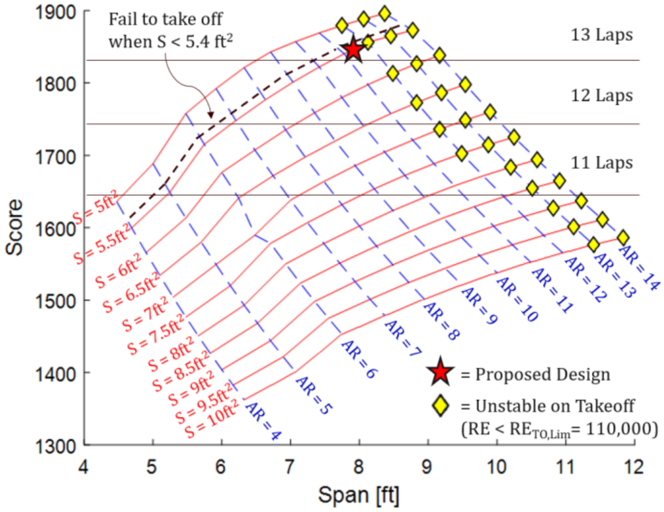


Figure 4: Total Score vs wing AR, S and b

Configuration Analysis > The team considered numerous configurations in the conceptual design phase. It was determined that a monoplane and blended wing body would be the highest scoring configurations. Analysis was performed to compare the two configurations; it was determined that despite the ability for a blended wing body to carry more attack stores for M_3, its dynamic instability and CG placement were major issues. Moving forward, the monoplane configuration will be used as it balances stability, payload storage, and CG placement.

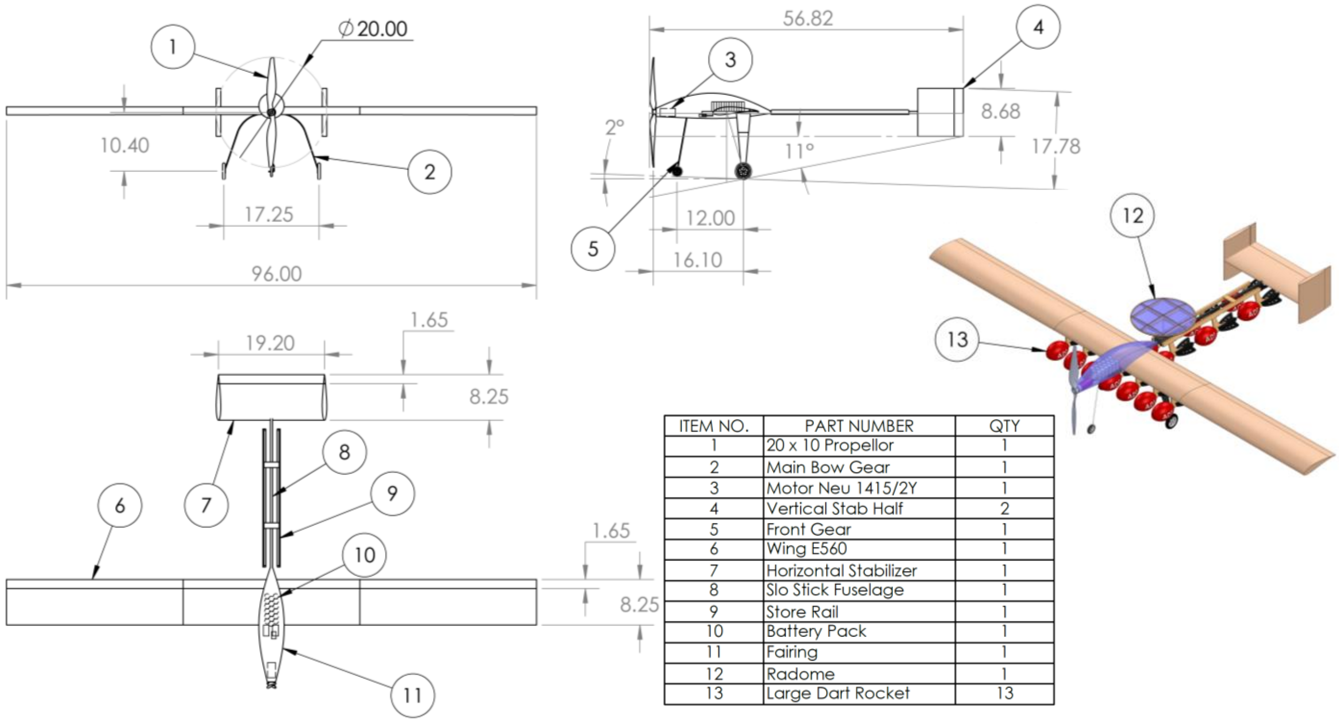
Preliminary Design > The team collaborated to design all aircraft components to meet the three design objectives: 1) make takeoff field length (TOFL) requirement, 2) adhere to spatial constraints, and 3) maximize score for M_3.

Wing Geometry > Trade studies were performed on airplane performance characteristics at all phases of flight, including takeoff, climb, cruise, and turns. Using a MATLAB-based simulation written by the team, trades were performed to study parameters such as TOFL, climb rate and cruise conditions, as well as propulsion parameters (e.g., thrust and current draw). The aircraft was sized by simulating a range of wing areas (S), wingspan (b), and aspect rations (AR) for a set propulsion package. The tradeoff between wing geometry and score is shown in Figure 4. To avoid problems with stall at low Reynolds numbers, the region in the figure is denoted with yellow diamonds to remain above Re = 110,000. The TOFL limitation is also denoted with a black dotted line. The preliminary configuration, shown as a red star, has AR = 11.6, S = 5.5 ft^2, and b = 8 ft.

Aerodynamics > In order to meet the TOFL requirement and ensure adequate performance, various airfoils were compared to attain a high C_{Lmax} for takeoff and low in-flight drag during cruise. The wing configuration for the preliminary aircraft was designed using two airfoils and analyzed using AVL, a 3D inviscid flow analysis tool. The E560 airfoil was used due its high C_{Lmax} of 2.0 with 20° flaps and low $C_{DCruise}$ of 0.0125.

An H-tail configuration was selected for the tail because of the vertical spatial constraint of 2 feet. Stability analysis shows that both a conventional and an H-tail would be stable in flight even with radome interference from M_2; however, the span on the vertical stabilizer of the conventional tail needed for stability exceeded the vertical spatial constraint. Further dynamic stability was conducted on the overall aircraft and showed that all modes were stable except for the spiral mode, which can be mitigated by implementing dihedral into the wing if deemed necessary after flight tests.

Propulsion > To meet a 10 foot TOFL, analysis determined that a static thrust greater than 10 lbf was needed for takeoff. After looking at various motor, battery, and propeller combinations, a preliminary propulsion package consisting of one Neu 1415/2Y motor was selected with an APC 20x10E propeller and 18x Tenergy 4200mAh NiMH cells. This package meets the performance requirements for all flight missions, allowing the aircraft to takeoff in 10 feet and sustain flight for the duration of the 10 minute window in M_3 to achieve a higher number of laps.



ITEM NO.	PART NUMBER	QTY
1	20 x 10 Propellor	1
2	Main Bow Gear	1
3	Motor Neu 1415/2Y	1
4	Vertical Stab Half	2
5	Front Gear	1
6	Wing E560	1
7	Horizontal Stabilizer	1
8	Slo Stick Fuselage	1
9	Store Rail	1
10	Battery Pack	1
11	Fairing	1
12	Radome	1
13	Large Dart Rocket	13

Figure 5: Preliminary Design of the Aircraft – 3 View and Bill of Materials (all dimensions in inches)

4.0 Manufacturing Plan

The initial schedule for aircraft and component production is shown in Figure 2. The team builds a number of prototypes in order to validate analysis and gather data that can be used to improve the preliminary design. The CAD Lead designs the aircraft based on data from the Performance, Aerodynamics, and Propulsion Leads. Completed design drawings are passed to the Structures, Manufacturing, and Payloads Leads, who sign off on the design, select materials, and lead the manufacturing effort. The manufacturing flowchart is shown in Figure 6.

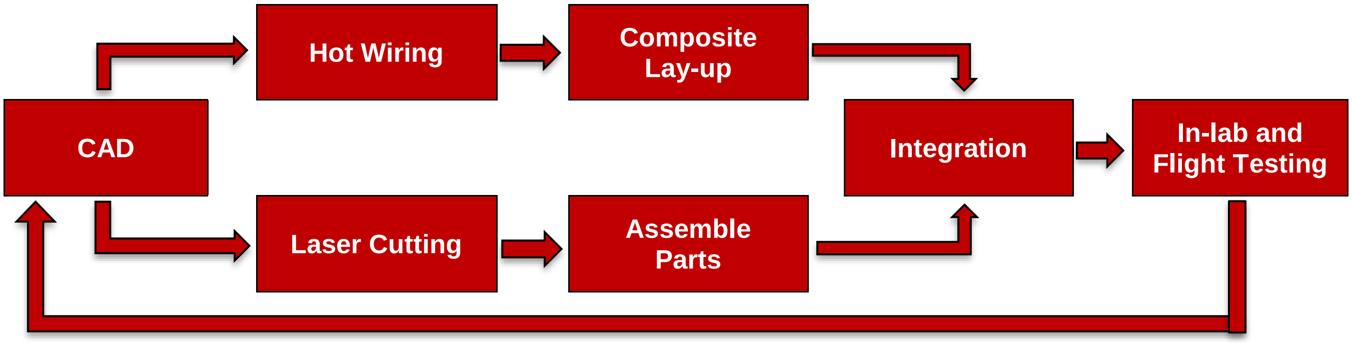


Figure 6: Manufacturing Flowchart

The team has completed prototypes for the preliminary design of the aircraft subcomponents; the prototypes for the wing folding mechanism, radome structure, and attack store attachment mechanism are shown in Figures 7-9, respectively. The wing mechanism folds the wing upwards and on top of itself. A servo locks the wing in stowed configuration by deflecting the ailerons and using it as a hook. The servo actuates the aileron back to neutral position, which then transitions the wing to the flight configuration with a spring and lock. The radome is constructed with a balsa outer ring, waffle patterned ribs, and covered with a SOLITE skin to minimize drag. The attack store attachment mechanism mimics a hairclip that attaches at the thickest part of the store to reduce in-flight movement. This mechanism also retracts into the fuselage following a store release, allowing drag to be minimized. The team is currently working on designing, building, and testing components for integration onto the first flight test aircraft.

Figure 7: Wing Folding Mechanism

Figure 8: Balsa Radome

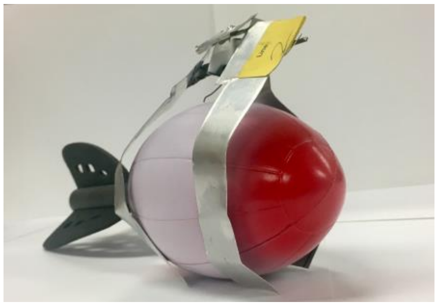


Figure 9: Attack store Attachment

Based on the team's collective experience and current design objectives, the fuselage will consist of molded composites and a lightweight foam truss that transfers in-flight and landing loads. The wing will consist of a plywood spar, balsa ribs, carbon D-box, and SOLITE skin. Further structural analysis with finite element analysis (FEA) will be used to design, build and test multiple iterations of the fuselage and wing in order to identify the lightest approach and improve build techniques. Development of wing folding, radome rotation, and store dropping mechanisms will occur concurrently with the development of the plane's landing gear, wing, tail, and fuselage.

5.0 Test Planning

Prior to the contest, all components and missions will be tested through a combination of in-lab and flight tests. Flight tests are scheduled at the conclusion of the build cycles shown in Figure 2. The test flight plan for the first iterations of the full aircraft prototype will be to validate TOFL and wing sizing. During the second iteration, the propulsion system performance will first be evaluated for static conditions using the RC Benchmark 1580 series dynamometer. Then, data will be collected at test flights using an electronic speed control (ESC) with an integrated data logger to optimize dynamic performance of the propulsion system. Landing gear will be tested in lab and at flight tests for ground maneuverability and to withstand takeoff and landing loads. Additionally, in-lab testing will be done on the rotating radome and the attack stores to ensure that the components can rotate and drop, respectively. These early iterations of the full aircraft will be constructed out of foam. Once all components are validated, balsa and composite sections will be constructed and tested in lab to ensure structural integrity, then flight tested to validate load transfer of the folding wing mechanism and payload mechanisms. Lastly, a flight test will be conducted with the team's actual competition aircraft to simulate all missions and trim the aircraft for the contest.