Johns Hopkins Design Build Fly Team

2017-18 Competition Proposal

Executive Summary

This proposal contains the planned design, analysis, manufacturing, and testing to be carried out by the Johns Hopkins University Design, Build, Fly team for the 2018 AIAA Design/Build/Fly competition.

The team's objective is to design, manufacture, and test an unmanned radio controlled (RC) aircraft capable of carrying passengers and payload while minimizing the wingspan and empty weight of the aircraft. The aircraft will complete a ground mission involving the demonstration of line-replaceable units (LRUs), and 3 flight missions requiring the transport of "passengers" (rubber balls) and "payload blocks".

In order to create a unique and innovate aircraft for the spring competition, The JHU DBF team has split into 4 independent design groups-- each pursuing the design and fabrication of their own unique solution to the challenge. The conceptual and preliminary solution of *one of these teams* is discussed in this proposal.

The team performed a sensitivity analysis and identified that low RAC, moderate passenger count, and low payload weight are the optimal parameters to pursue. The team's solution to the design is a single-motor, wide fuselage biplane designed to carry 24 passengers.

Management Summary

The management system in the fall consists of a president, chief engineer, treasurer, and four parallel design groups consisting of 4-5 members (see *Figure 1*). The president and project manager will oversee progress in each design group and the treasurer will manage finances. These four design groups will design and manufacture their own planes. They will then compete against one another in December to determine which design (or elements of multiple designs) will be pursued in the spring for competition.

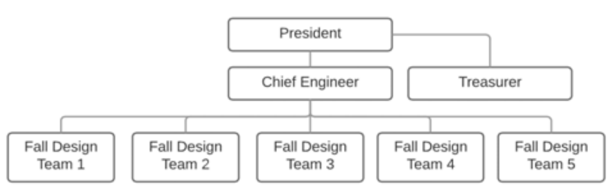


Figure 1: Fall Design Organization Structure Chart

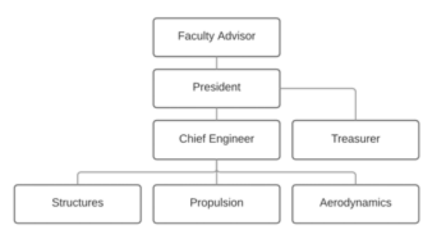


Figure 2: Spring Organization Structure Chart

After the four design groups compete in December, all members will direct their attention toward the design of the plane that has been chosen for competition. With one plane design, the spring management system retains the roles of the president, chief engineer, and treasurer. Parallel design groups are collapsed, and aircraft component sub-team leaders are introduced (*see figure 2*). Aerodynamics, structures, and propulsion leaders guide groups of 5-7 members toward refining their respective subsystems with analysis and physical experiments. Roles and required skills for each leadership position are discussed in *Table 1.*

Table 1: Leadership Position Roles and Skills

President	Chief Engineer	Treasurer	Structures	Propulsion	Aerodynamics
- Effective communication - Ability to motivate	- Technical Expertise - Distribute work effectively	- Organized - Realistic - Impartial	- Structural Design/Analysis - Manufacturing methods	- Power train design - Analysis of motor thrust	- Fluid dynamics analysis - Lift/Drag calculations

Any member may approach the team with an idea or problem. The sub-team leader will then communicate with the other sub-team leaders, president, and chief engineer to ensure that all decisions are approved by management of the club. Discussion with management will ensure that all opinions are heard and that each decision is made as a team.

It is imperative that the chief engineer requires each fall design team to stay on schedule. He/She will remind each fall design team of the gantt chart (see Figure 3) and what is required to have a successful preliminary design review, critical design review, and final prototype.

The treasurer will be responsible for keeping the team from exceeding the budget for electronics, structure, manufacturing, and travel (see Table 1). He/She will also be lead the fundraising effort where JHU will focus on mainly on obtaining additional funding through corporate sponsors from local engineering companies.

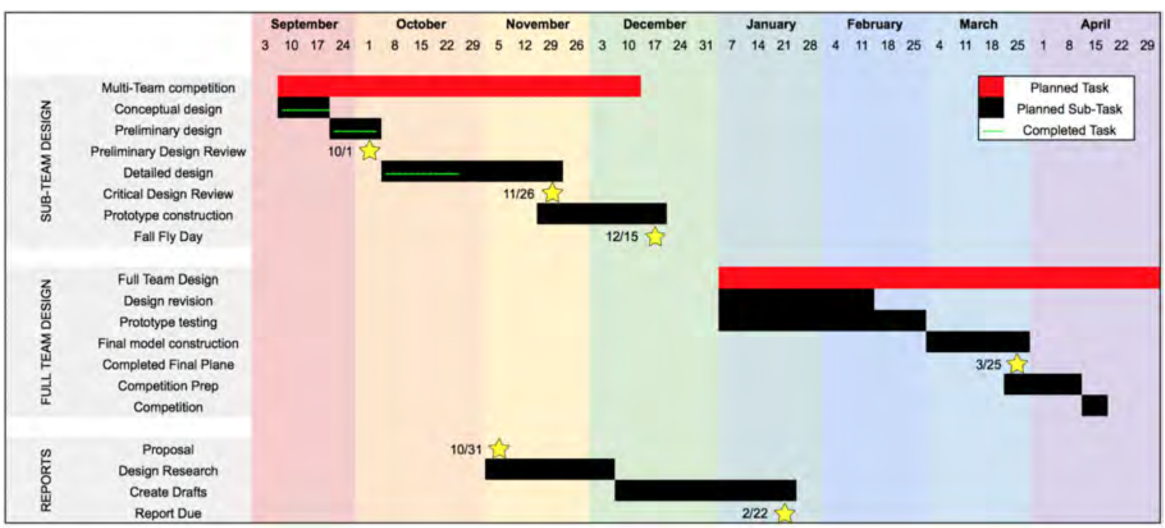


Figure 3: Gantt Chart

Table 2: Estimated Budget

Assets	
Cash	93.31
Income	
Whiting School Contribution	1000
Dean's Scholarship	1000
CEAFM Lab Contribution	750
	2750
End Year Assets	2843.31

Construction Expenses	
Electronics	
4x 6 Cell Batteries	$140.00
5x ESCs	$210.00
1x Transmitter	$75.00
4x Rx Receiver	$75.00
6x Motors	$250.00
8x Servos	$70.00
1x Battery Charger	$45.00
Misc (pushrods, links, etc)	$50.00
	$915.00
Structure	
1/4" and 1/8" Balsa	$235.00
5x Monokote Rolls	$120.00
CF Layup Kit	$60.00
Misc (hinges, screws, etc.)	$100.00
	$515.00

Manufacturing (Provided by JHU Machine Shop)	
Laser Cutting	$450.00
3D Printing	$200.00
CNC Mill	$120.00
	$770.00
Travel/Other Expenses	
3 Nights in Hotel	$450.00
Rental RV or Car (Plane Travels in Car)	$520.00
Gas	$185.00
	$1,155.00
Total Expense	$2,585.00
Net Gain/Loss	$258.31

Conceptual Design Approach

This year's competition rules introduce challenges related to transporting passengers and shipping cargo. The aircraft must complete one ground mission and three flight missions:

Ground Mission: Select aircraft components (*Line Replaceable Units*) must be replaced by the team.

Flight Mission 1: The plane must complete three laps of the designated course in five minutes with no payload.

Flight Mission 2: The plane must complete three laps of the designated course in five minutes with a number of passengers specified by the team.

Flight Mission 3: The plane is given five minutes to maximize the product of number of passengers, payload weight, and laps completed.

The team's score is a function of report score, mission scores, and the RAC. Mission scores are formulations of cargo carried and flight performance, and the RAC is a product of the aircraft's wingspan and empty weight. The team performed a sensitivity analysis to determine combinations of variables which would produce a successful, high-scoring plane. Assumptions were made for baseline aircraft parameters and top team performance in both missions 2 and 3. Independent variables (shown right in legend) were each varied; other physical parameters used in the calculation were approximated.

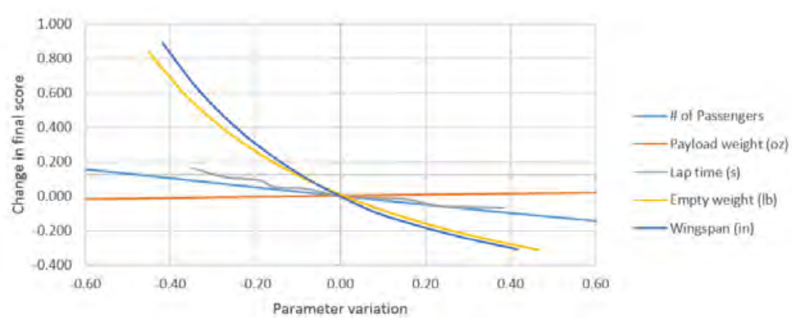


Figure 3: Sensitivity study of aircraft and competition parameters

The analysis shows that the total score is most sensitive to wingspan and empty weight (both factors of the RAC)-- suggesting that building a smaller plane with lower payload capacity will yield a higher score. The study also suggests that increasing passenger count is more important than increasing payload weight.

In choosing the aircraft configuration, the team prioritized a small wingspan, low structure weight, and moderate passenger capacity. After performing trade studies, the team chose an aircraft configuration featuring a single tractor motor, biplane wings, a wide fuselage, a tail boom rear fuselage, and a traditional empennage. A biplane structure has a smaller wingspan than a monowing structure with comparable planform area, resulting in a smaller RAC. The fuselage is sized to fit six rows of four passengers, centered at the center of pressure. The tail boom reduces rear fuselage weight; traditional empennage and tractor propulsion were selected for their simplicity and proven performance in commercial aircraft.

LRUs were viewed as design features independent of the major aircraft features. All pushrods will be assembled with a clevis and z-bend for easy removable. Control surfaces mounted on hinges will be screwed into the flight surfaces; landing gears, motors, and servos will be mounted to basswood formers by screws. Electronics LRUs can be mounted within the fuselage using velcro. Sizing calculations were performed using approximations of drag, lift (wing area), fully loaded aircraft weight, and electric motor power. *Figure 4* shows preliminary dimensions of the major features.

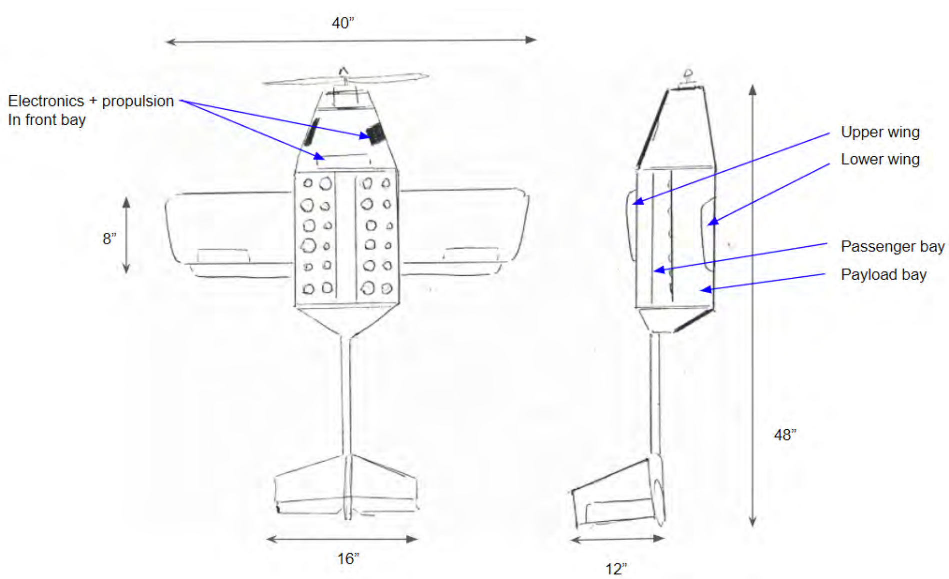


Figure 4: Isometric view of major aircraft features

Manufacturing Plan

The materials necessary for manufacturing the airframe include balsa, basswood, foam, fiberglass, and monokote. The wings will be made from foam that is hot wire cut to the selected airfoil. In order to strengthen the wing in bending and torsion, fiberglass cloth will be added and adhered to the wing structure using epoxy. The fuselage and empennage of the plane will be made from balsa and basswood. The wood will be cut using a laser cutter. Regions that are identified as high stress areas will be reinforced with carbon fiber cloth and tape. The nose of the plane will have carbon fiber placed up on the balsa wood to allow it to withstand the high impact forces it may be subjected to in the result of a crash. After the components of the plane are manufactured they are assembled using screws and adhesives, then the fuselage is coated with monokote.

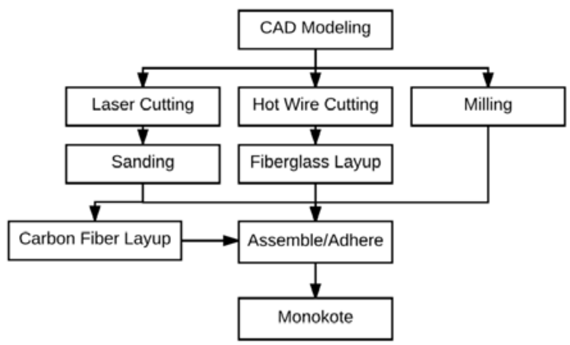


Figure 5: Manufacturing flow chart

Test Planning

A series of subsystem tests will be performed during the design revision and prototype testing phase of the project.

Thrust measurements using a thrust stand will be taken for the powertrain that is being used in the winning fall design prototype. Selection of motor, battery, and propeller will be revised based on findings from the tests. After each prototype is built, the plane will undergo a wing tip test at 1.2x its maximum takeoff weight to ensure baseline structural integrity. The plane will then need to show its ability to complete every LRU task that is specified in the ground mission. If the plane is able to satisfy the LRU test, it will then attempt a taxi test where the plane will move and test control surfaces without taking off.

Flight tests will be used to refine airframe design and competition score. Pilot feedback will be used to modify lofted surfaces, major dimensions, and powertrain selection for subsequent builds. The team will also fly the competition course with various combinations of passenger count and payload weight in order to optimize scores for missions 2 and 3.

Rowan University

2017 - 2018

Executive Summary

The goal of the 2017-2018 Design, Build, Fly Competition (DBF) is to design a dual purpose regional and business aircraft. The aircraft will have to complete flight missions simulating the carrying of both passengers and payloads contained in separated, internalized compartments within the aircraft. The objectives of the design competition are to maximize the number of passengers along with payload weight and minimize the amount of time it takes the aircraft to complete the designated number of laps for each flight mission.

The objectives will be accomplished by analyzing each mission of the competition in order to determine the most important factors of the competition. The design stage will begin with a conceptual design of the aircraft immediately followed with a preliminary design created using a 3D modeling software. The designs will attempt to optimize the aircraft based on the importance of the competition factors as determined in the mission analysis. An aircraft design code script will be run in order to determine the nominal dimensions required for aircraft sizing to assist in developing the preliminary designs, along with proceeding design iterations. Utilizing the tools available in the 3D modeling software, Finite Element Analysis and Computational Fluid Dynamics will be performed on the aircraft to ensure it will be able to withstand the stresses during flight as well as to determine if the aircraft will possess the predicted aerodynamic properties. A simulation of the competition will be performed and the data obtained from the simulation will be used to further optimize the aircraft's capabilities.

Management Summary

To organize the DBF team, a team structure and roles were established (see Figure 1). Several main teams were formed to divide the design workload based on sections of the aircraft. Smaller teams were formed and roles were assigned to individuals to ensure that work on the entire project was evenly distributed.

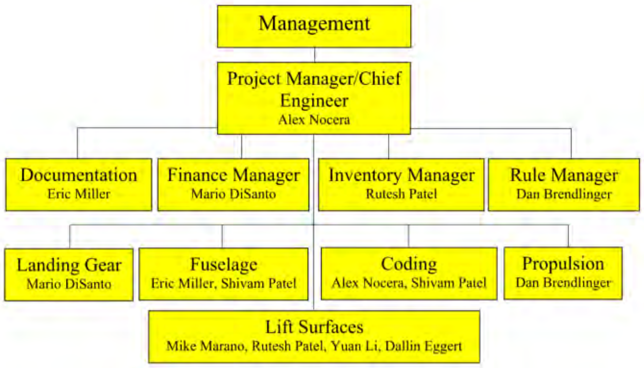


Figure 1. Team Structure and Roles

Each position's duties are described below.

- Project Manager / Chief Engineer: Lead the aircraft design, organize the project, keep the team updated on the competition specifications. Secure team funds, and work with University Public Relations to promote the project.
- Documentation: Ensure that each step of project development is being properly documented through photographs and recordings.
- Rule Manager: Ensure that the project abides by all rules and regulations of the competition
- Finance Manager: Maintain an up-to-date spreadsheet to manage finance. Secure funding and handle purchase orders.
- Inventory Manager: Maintain an up-to-date spreadsheet of current inventory. Develop the project list of required materials.
- Lift surfaces: Design lift surfaces that are lightweight, strong, easy to manufacture, and easy to assemble. Responsible for the wings, tail, and control surfaces.
- Fuselage: Design the fuselage to minimize size and weight while maintaining strength and durability to meet competition requirements.
- Landing gear: Design a compact, lightweight, easy-to-manufacture, and durable set of landing gear.
- Propulsion: Design, purchase, test, and modify the required components for the propulsion systems to optimize aircraft performance.
- Code: Develop the aircraft design code to help streamline design calculations.

After organizing, a schedule was made and translated into the Gantt Chart featured in Figure 2 below.

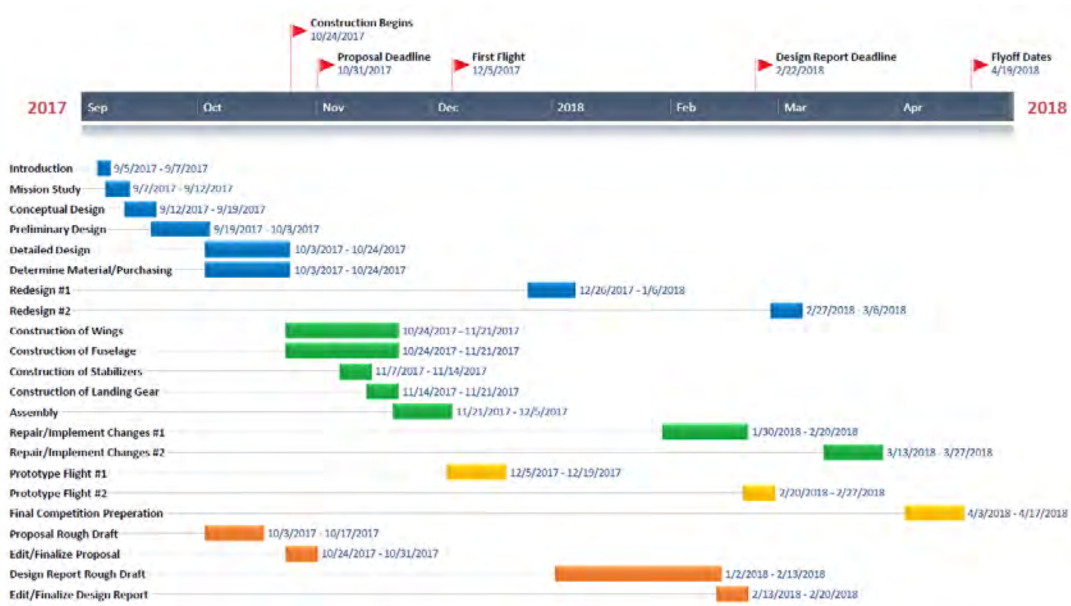


Figure 2: Gantt chart

A competition budget was also estimated. This budget includes material costs, manufacturing costs, and travel expenses (see Table 1 below).

Item Description	Max Cost
Hotel	$815
Travel	$755
Motor and Speed Controller	$170
Batteries	$165
PLA Plastic	$21
Glue	$50
Hardware	$50
Balsa Wood/Plywood	$100
Monokote	$85
Propeller	$15
Landing Gear	$25
Total Cost	**$2,251**

Table 1. Budget

Conceptual Design Approach

The mission of the 2017-2018 DBF competition is to develop a UAV to model a regional and business aircraft. It must be able to hold passengers and cargo. Certain aspects of the aircraft must be replaceable, called Line Replaceable Units (LRU's). Each team must complete three flight missions and one ground mission for maximum scoring.

Mission 1: Complete 3 laps in 5 minutes with no payload.

Mission 2: Complete 3 laps in 5 minutes with passengers

Mission 3: Complete as many laps as possible with passengers and payload.

Ground Mission: Certain parts of the aircraft must be replaced in 2 stages. Stage one involves the replacement of Field LRU's. Stage 2 involves the replacement of Depot LRU's.

Sensitivity analyses were completed for both the aircraft components and the missions. The analyses were conducted in order to reduce the Rated Air Cost (RAC), which affects the overall score. The RAC for the competition is determined by multiplying the empty plane weight by the wingspan length. The mission analysis was performed on missions 2 and 3, since mission 1 is a pass or fail flight with no other variables. The components of the second and third missions were analyzed to determine which variables will be easiest to adjust to increase overall score. The results of these studies are shown in Figures 3 and 4 for the aircraft analysis, and Figures 5 and 6 for the mission analysis.

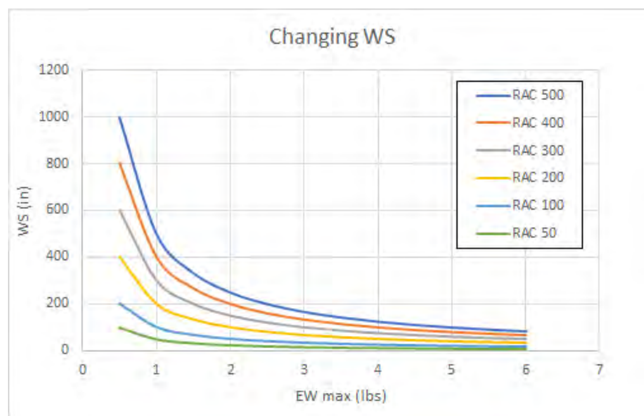


Figure 3. Aircraft Wingspan Sensitivity Analysis

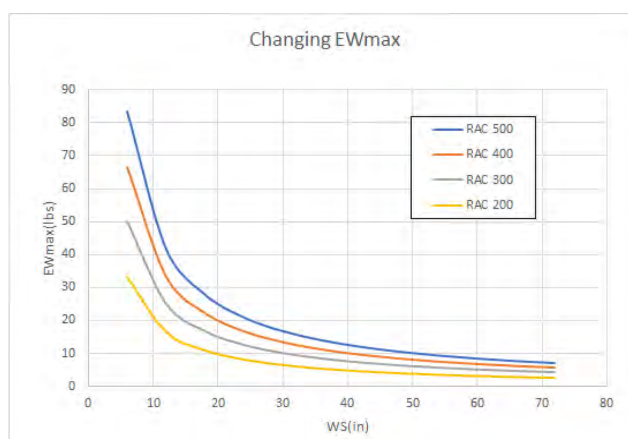


Figure 4. Aircraft Weight Sensitivity Analysis

The aircraft component sensitivity analyses in Figures 3 and 4 show that the design should focus on minimizing wingspan over minimizing weight, however reducing both is ideal.

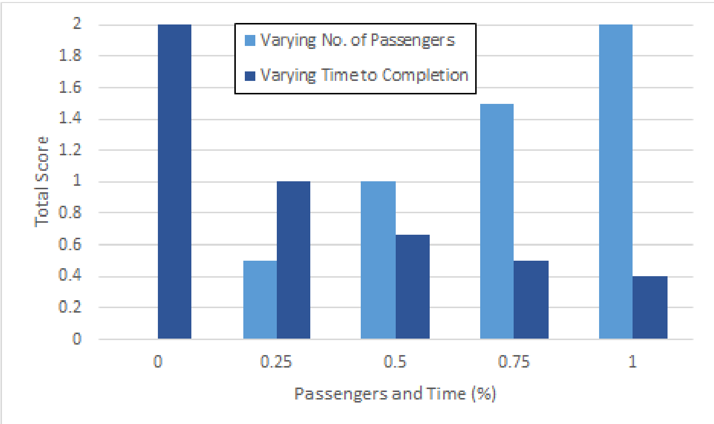


Figure 5. Mission 2 Sensitivity Analysis

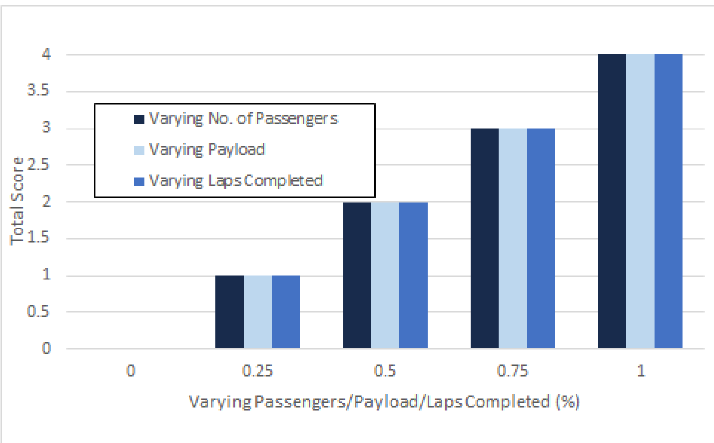


Figure 6. Mission 3 Sensitivity Analysis

The mission sensitivity analyses in Figure 5 and 6 shows that the focus should be on maximizing the amount of passengers carried in the aircraft. The increase in payload weight will have a positive effect on the overall scoring, but is creates more risks compared to maximizing the amount of passengers.

Conceptual Design Approach

Based on the mission requirements the aircraft must have easily replaceable parts, must be able to carry passengers of varying size and weight. The aircraft must be able to carry some payload underneath or behind the passengers, and the aircraft must be able to fly, fully loaded, for a minimum of three full laps.

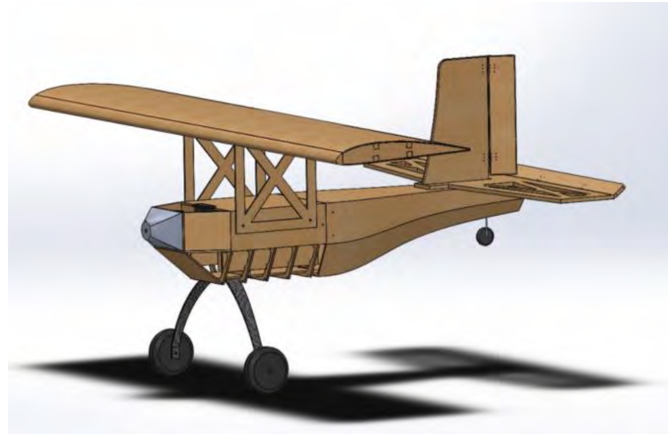


Figure 7: Preliminary design

The UAV will use a conventional wing, since it is more forgiving with changes to the center of mass. The wing will be raised above the fuselage to gain lift over the fuselage and reduce the overall wingspan. The rear tail will disconnect from the fuselage to create an accessible area to store both passengers and payload. Field LRU's will be connected to the aircraft with straps or screws so that the tools needed can be stored in the cargo bay. Some of these units – like the servo used to control the aileron – will be located on the plane's exterior for ease of access. In addition, depot LRU's will also be located on the exterior, or as close as possible. Table 2 shows the initial aircraft sizing.

Component	Size [inches]
Wing Length	40
Wing Chord	8
Vertical Stabilizer Height	8
Average Vertical Stabilizer Chord	4.05
Horizontal Stabilizer Length	14.5
Average Horizontal Stabilizer Chord	6
Fuselage Length	11

Table 2: Initial Aircraft Sizing

Manufacturing Plan

To streamline the construction process, the aircraft will be built in multiple sections.

First, the wing will be constructed using a balsa build-up method. The wing will be constructed by evenly spacing ribs laser cut from 1/8” balsa wood. The ribs will be connected by 1/4” square spars that run the length of the wingspan. On the rear edge of the spars, shear webs cut to size from 1/8” balsa will be attached to provide extra strength within the wings. A carbon fiber rod will be added on the interior of the wing through the ribs spanning 12” in both directions from the center of the wing. The rod will be located at approximately 35% of the chord length from the leading edge of the main wing. The leading edge of the wing will be constructed by sanding down leading edge material into the correct profile and connected to the ribs. Winglets will be added to the tips of the wings. After the main structural elements of the wing are all constructed the wing will then be covered with 1/16” balsa sheet and attached to the fuselage using braces laser cut from 1/8” plywood.

The vertical and the horizontal stabilizer will be made from a flat sheet of laser cut 1/4” balsa wood. The horizontal and vertical stabilizers will be attached to the fuselage via the tail section.

The control surfaces – ailerons, elevator, and rudder – will be constructed individually. The ailerons will be sanded down to match the trailing edge profile of the main wing. The elevator and rudder will be laser cut from 1/4” balsa wood.

The tail section of the aircraft will be constructed by laser cutting varying sized formers from a 1/4” balsa sheet. Stringers will be run across the corner of the formers. The tops and bottoms of the formers will then be connected by 1/8” balsa sheets cut to size. Then the tail section will be wrapped with Monokote to seal all gaps. It will then be attached and secured to the back of the fuselage via plastic screws.

The fuselage will be constructed in two primary sections: the nose cone and the main fuselage body. The nose cone will be constructed in a pyramid form. There will be a small sheet of 1/8” balsa at the tip and base of the pyramid structure. There will be a support structure in between the tip and base to support the electronic components. The structure will then be wrapped in Monokote, secured in place with Velcro. The main body of the fuselage will be constructed in modular sections: one for the passenger bay and one for the payload bay. All sections of the main body will be constructed from 1/8” balsa wood with 1/32” plywood secured with glue. The passenger compartment will be utilizing 3D printed parts and elastic bands in order to secure the passengers in place during flight.

Test Planning

Prior to final completion of the aircraft, the components will be subject to several ground tests. The propulsion system and components will be attached to a rig constructed for measuring battery current and voltage, as well as thrust provided from the propeller, over a specified period of time. The propulsion tests will determine overall propeller efficiency and thrust force available with the selected battery and propeller.

The aircraft will then be fully assembled and will undergo several other tests. Multiple timed tests will be performed to ensure the LRU components are all able to be removed and replaced within the required time for the ground mission. The tests will be performed to simulate the competition as best as possible; the LRUs will be selected and removed in the order that would occur during the actual competition. The aircraft will be subject to a wing tip test to ensure that the wings will be able to withstand the load of the aircraft. The control surfaces and propulsion system will also be tested upon full assembly of the aircraft prior to first flight.

Finally, the first prototype of the aircraft will be subjected to extensive flight testing in early December, following a mock competition course in order to collect real-time data. The data collected will be utilized to refine and rebuild the aircraft for the second prototype. Further flight tests will be conducted in mid-February, and results from those tests will be used to perform final modifications and fixes on the aircraft.

<u>University of California, Los Angeles</u>

Design/Build/Fly 2017-18 Proposal

1.0 Executive Summary

This proposal describes the preliminary analysis and design for UCLA's Design/Build/Fly team for the 2017-18 competition. The objective is to design and produce a remote-controlled aircraft that successfully meets, and optimizes, the competition's rules and requirements to maximize the team's overall score. This year the competition requires the aircraft to carry "passengers" and cargo in separate compartments, modeling a conventional business or regional aircraft. Additionally, the aircraft's major components must have the ability to be easily removed and replaced to satisfy the ground mission. The score is influenced by several components: the three respective mission scores, written report score, empty aircraft weight, and wingspan.

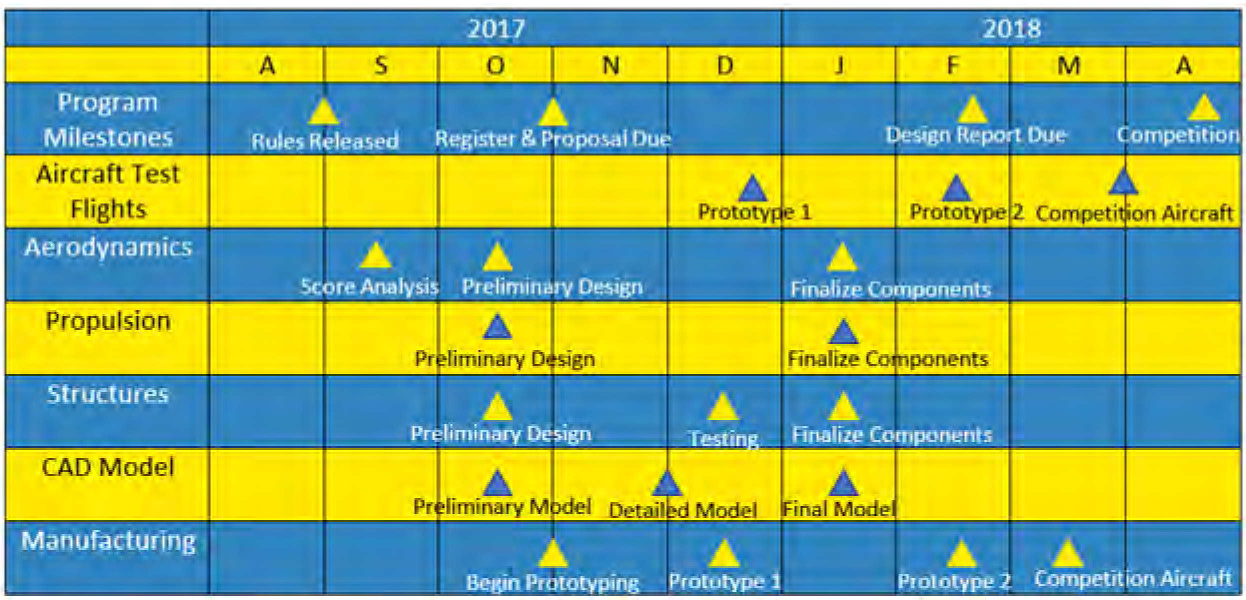
The continuous approach to achieving all objectives is as follows. After the release of the competition rules, an in-depth score analysis determined which parameters to center the design around. Next, concept sketches were created to gain an overarching idea of the plane's major components and conceptual design. Once a conceptual design is completed, sizing is optimized to ensure the aircraft can meet all performance requirements, as well as produce the highest score possible. Currently the team is creating CAD models of the entire aircraft in order to begin manufacturing the first prototype. After a prototype has been built, the aircraft will be analyzed and tested based on its performance capabilities. This prototype will then be redesigned or adjusted based on the results of the testing, and this process will repeat until the final version of the aircraft is created and proven to meet all the requirements.

2.0 Management Summary

The team is divided into both managerial and technical leads. The Project Manager oversees the entire team, and her duties include organizing and leading team meetings, coordinating with the local AIAA chapter, budgeting and acquiring funding, and ensuring all deadlines are met. In coordination with the Project Manager, the Vice Project Manager, with any necessary tasks. Bridging the gap between the managerial and technical leads, the Chief Engineer is responsible for the overall design and manufacturing of the plane, as well as working with the Project Manager and other technical leads to ensure overall project efficiency. Under the leadership of the Chief Engineer are the five main technical leads organized into the following categories: aerodynamics, structures, CAD, propulsion and manufacturing. These leads were chosen by the Project Manager and Chief Engineer based on their knowledge and experience in their respective fields. Each technical lead also commands a team to accomplish any and all tasks throughout the project season.

2.1 Organization Chart

2.2 Schedule and Major Milestone Chart



2.3 Budget

The table below is a generalized form of our budget for this competition season. The wood, adhesives, and laser cutting are intended for wing and tail construction, while the carbon fiber components will be used for the construction of the aircraft's fuselage. A miscellaneous portion of the budget was allocated in case of inaccurate price estimates, as well as unforeseen expenses since the design is subject to change throughout the course of the year. Using estimates from prior competitions and researching rates, the travel costs of attending competition is where a significant amount of the funds are allocated.

Our team funds come from sponsorship of various companies, including Northrop Grumman and Boeing. Additionally, as a part of the AIAA chapter at UCLA, the team actively participates in sponsorship events to generate more money for the organization. The team also receives funding from smaller groups, like UCLA's Engineering Alumni Association and the University Student Association Commission.

ID	Item	Description	Proposed
1	Wood	Balsa & Spruce	$400
2	Carbon Fiber	Woven Cloth, Epoxy & Resin	$750
3	Propulsion System	Motor, Batteries, Propeller	$550
4	Servos	Control Surfaces	$200
5	Laser Cutting/CNC	Cutting Wood & Foam	$400
6	Glue/Adhesives	CA, Foam Safe	$120
7	Miscellaneous	Nylon Hinges, Landing Gear, etc.	$500
8	Travel	Car Rental (3) and Gas @ $3.00/gal	$2000
9	Hotel	4 Rooms @ $80/night for 5 nights	$1600
		Total Projected Cost	**$6,520**

3.0 Conceptual Design Approach

This year's competition consists of three flight missions and one ground mission. Mission one requires a demonstration flight without a payload. Mission two includes carrying "passengers" restrained internally to complete three laps in as short a time as possible. Mission three involves carrying a combination of passengers and cargo blocks and completing as many laps as possible in a ten-minute window. The ground mission consists of the removal and replacement of Line Replaceable Units chosen from a dice roll. This requires most components of the aircraft to be easily removed and installed.

A sensitivity study was carried out on the scoring equations for each individual mission and the overall score, which found seven varying parameters that determine the final mission score [Figure 3.1.] The variables involved in mission two are the number of passengers carried and overall completion time, while the mission three score is dependent on the number of passengers, total payload weight, and number of laps completed. Additional parameters that affect scoring are the overall maximum empty weight and the aircraft's wingspan. Reasonable estimates were used to find the aircraft's approximate parameters, and a first-guess score was generated. From there each of the seven parameters were individually varied by a percentage to see which design parameters had the greatest impact on scoring.

The sensitivity study reveals that reducing the plane's empty weight and wingspan have the largest benefit on mission score while other parameters, such as number of passengers carried and laps completed, had less of an impact on the overall score. Furthermore, increasing the number of passengers and payload weight for the second and third missions was found to decrease our mission score because it required increasing the wingspan, and subsequently the empty weight. For this reason, it was decided to design a plane around the minimum number of passengers and payload allowed: two passengers for mission 2, and one passenger and one payload block for mission three. Our design point will center around keeping a low empty plane weight and a smaller wingspan in order to achieve a higher mission score.

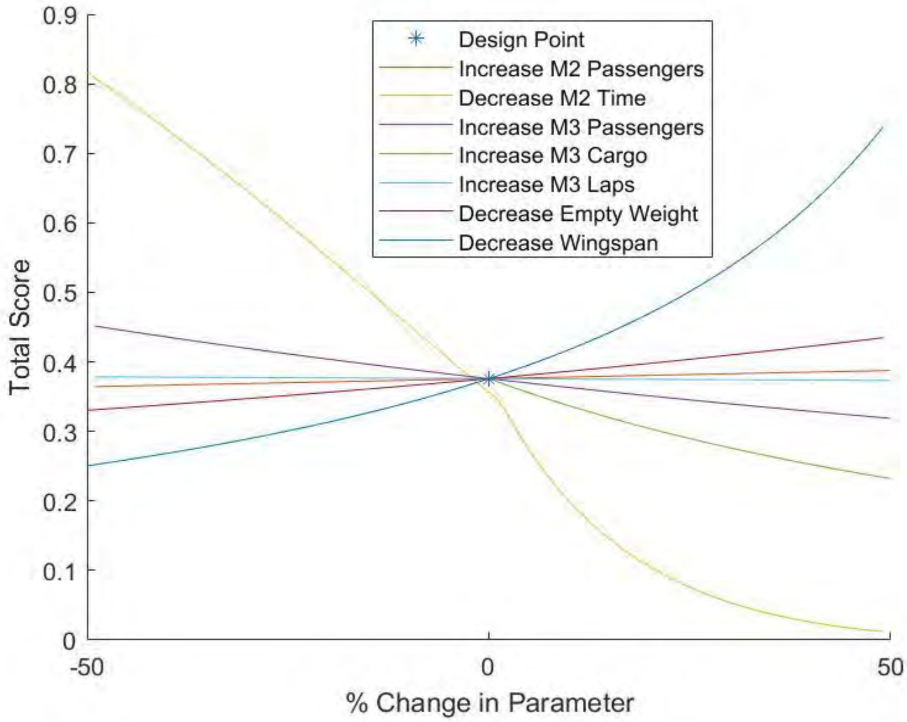


Figure 3.1: ***Results of sensitivity study.*** *The line representing M2 Time is inaccurate as of the writing of this report.*

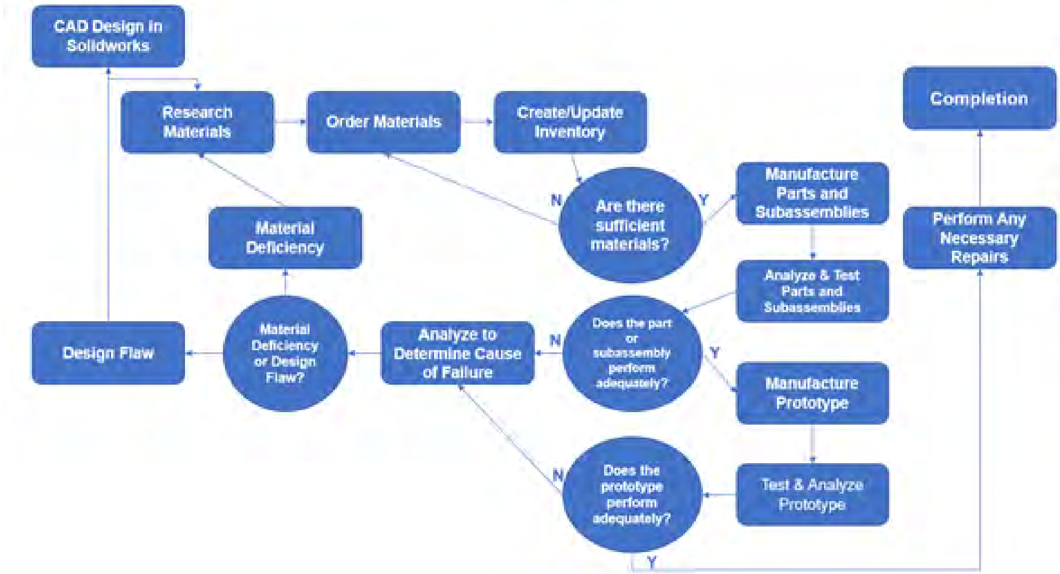
General sizing was conducted by starting with best-guess parameters. Constraint plots were generated based on power requirements at each phase of flight, which were used along with stability calculations to size the aircraft. From there, an optimization process was run, randomly varying aircraft parameters and observing their effect on score in order to select an optimum configuration.

The aircraft is planned to incorporate a high, rectangular wing and tractor motor, a conventional tail, and conventional landing gear. An aerodynamic fuselage will contain two layers, the upper holding passengers and the lower holding cargo, with a removable divider for loading. Preliminary results show an optimized wingspan of approximately 16.19”, a chord length of 4.1”, and a 126 W max power propulsion system, for an anticipated total weight of 1.8 lbs.

4.0 Manufacturing Plan

Critical processes and technologies required will include 3D printed molds of the fuselage design, laser-cutting of balsa and spruce wood for construction of the wing, heat-gun technique for monokote, and carbon fiber/fiberglass wet-layup on the 3D printed molds via vacuum for the fuselage. Basic machining and finishing include use of rotary tools, hand drills, files, cutters, etc.

4.1 Preliminary Manufacturing Flow



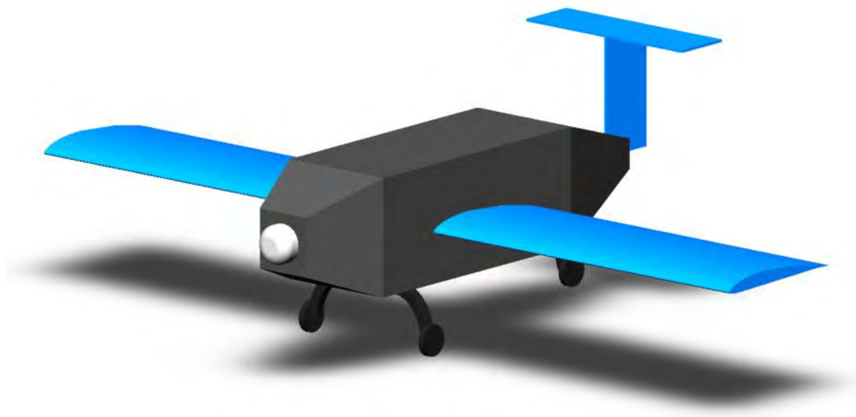
5.0 Test Planning

Component testing will encompass testing of the propulsion performance, integrity of the airframe and accessibility and survivability of the removable parts:

1. *Propulsion System Testing*: The battery pack and motor will be tested using an RC plane motor test stand and a meter will be used in the circuit in order to measure the output parameters of the battery such as its voltage, current, and amperage. This will test the battery pack under load in order to make sure that the voltage drop and capacity meets expected requirements at assumed flight conditions. The motor test stand will enable the testing of static thrust (lbf) that the motor and propeller setup is giving out. The entire propulsion system will be tested in controlled intervals with full-throttle discharges to verify endurance calculations.
2. *Airframe Testing*: Wings will be wingtip tested under a +/- 5G loading to verify the survivability of the plane under handling loads, flight loads, and landing load. Carbon fiber tubes used for the tail boom of the plane will be tested using similar concepts.
3. *Replacement Testing*: Parts that are required for replacement during the ground missions will be tested by practice replacement to determine the accessibility of removing the parts and the survivability of the connecting mechanism.

Flight testing will begin without a payload to ensure safe testing of propulsion system performance, stall velocity, max velocity, and so on. If the plane performs to predicted standards, then it will be tested with an incrementally increasing payload weight. At max payload, flight performance will again be evaluated.

2017/2018 AIAA Design/Build/Fly Proposal



1. EXECUTIVE SUMMARY

This proposal details the design to date of an unmanned, electric-powered, radio controlled aircraft by the students of the University of Nebraska-Lincoln (UNL) for the 2017/2018 AIAA Design/Build/Fly (DBF) competition. The objective of the team is to design and manufacture an aircraft that mimics a dual purpose regional and business aircraft. This aircraft must be capable of transporting passengers with individual restraints and an accompanying cargo block behind or below the passengers. In addition to the payload, the aircraft must be able to simulate repairs in the form of replaceable components, defined as Line Replaceable Units (LRUs). Mission score will be affected by other teams' performances on the designated missions, but a major factor that is reliant on the team's design is reducing the Rated Aircraft Cost (RAC). Reducing the RAC will be accomplished by detailed sensitivity analysis to reduce the wing span perpendicular to the fuselage (WS) and empty weight (EW); both of which are the only factors in the RAC. To achieve the highest score, the aircraft must be able to withstand and fly quickly in high winds, as well as carry large payloads in the form of number of passengers and weight of cargo. In addition to these goals, the complete design will balance effective aerodynamic analysis to ensure successful flights. Through successful analyses coupled with viable testing methods and effective manufacturing techniques, the UNL DBF team is confident in the creation of an aircraft that surpasses all other teams.

2. MANAGEMENT SUMMARY

The University of Nebraska-Lincoln team uses a hierarchal structure to coordinate responsibilities among the experienced members which are then transitioned to new, inexperienced members. A faculty advisor acts as a source of experience and a professional representative of the team. A team lead acts as project manager in all aspects, as well as a liaison with the college of engineering. This position requires great organization, communication, and leadership skills. All work was divided into four sections: Manufacturing and Testing; Aeronautics; Propulsion and Controls; and Design. Each section is designated a lead in order to delegate and organize the work load. Section leads must possess the necessary skills and knowledge of each subject. To be in each team, members must have a willingness to learn and collaborate, however, no prior experience is needed. Experienced members provide opportunities to learn and explain the design process to new members to help them assimilate for future competitions. This structure only serves as an outline to improve communication and organization; most individuals participate in multiple teams to achieve a set task and produce a successful aircraft. The hierarchal structure can be seen in Figure 2.1.

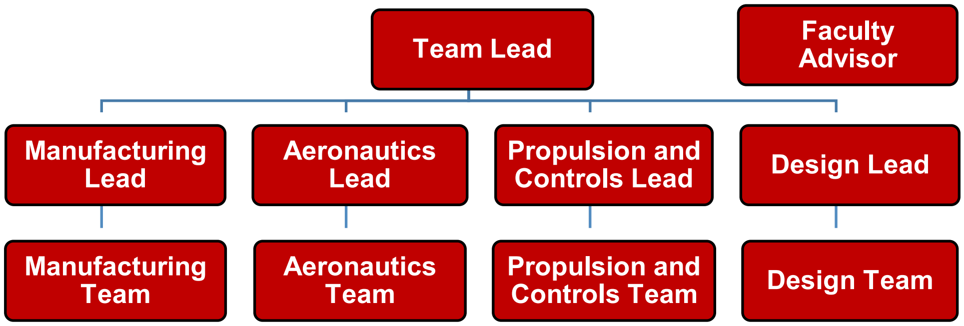


Figure 2.1: Team organization chart.

A milestone chart was established by all leads at the beginning of the school year to determine major deadlines for each phase of design, manufacturing, and testing to achieve success at competition. Team leads are responsible for ensuring that each deadline is met. The team frequently meets with the faculty advisor to update them on the progress of the team. The actual and planned timing can be seen captured in the timeline in Figure 2.2.

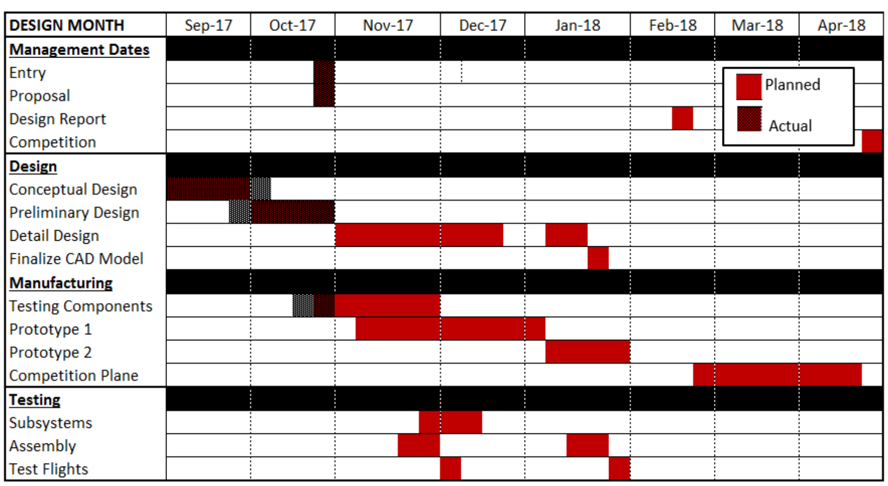


Figure 2.2: Milestone chart.

The leads also established a budget at the beginning of the school year to incorporate all cost aspects of the design: material, material shipping, tooling, travel, and lodging. The budget is constantly monitored by the team leads to ensure the necessary funding for the totality of competition. This budget's total was chosen in reference to past funding projects that the team has worked with. Our main source of funding each year is through NASA Nebraska. NASA Nebraska is a great source of networking and serves as a communication link to the aerospace industry for the students involved. Any extra projects that need funding are submitted through the UNL's Engineering Student Advisory Board. This involves small proposal presentation and deliberation within the group. The initial budget can be seen in Table 2.1.

Table 2.1: Budget.

Category	Cost	Description
Ready-Made Parts	$1,100	Propellers, motor, batteries
Radio Control Equipment	$500	Transmitter, receiver, wires, servo, etc.
Construction Material	$1,200	Balsa, carbon fiber, foam, plastic, etc.
Tools and Other Supplies	$175	Tools and other supplies
Shipping Costs	$25	Shipping costs for materials and tools
Manufacturing Cost	$1,200	Molding, laser cutting, 3D printing
Fuel	$280	570 miles – 2 vehicles
Vehicle Rental	$1,300	2 vehicles – 5 days
Day Trip to Supplier	$60	300 miles – 1 vehicle, gas and rental
Hotels	$960	3 rooms - 4 nights, $80/room/night
Food	$1,200	$20 for meals – 5 days – 12 members
Total	**$8,000**	

3. CONCEPTUAL DESIGN APPROACH

To achieve the main objective, all mission requirements (Table 3.1) must be met while minimizing the RAC (Equation 1). The value of this year's mission score is based on completion with a heavy factor on other teams' scores in regards to speed and payload capacity.

Table 3.1: Basic mission requirements.

Mission Number	Objective	Time Limit	Payload
1	Fly 3 laps	5 minutes	None
2	Fly 3 laps	5 minutes	Chosen amount of Passengers
3	Fly as many laps as possible	10 minutes	Cargo and a minimum of half amount of max Passengers
Ground Mission	Replace two components	8 minutes	Tools for component replacement

$$RAC = EW * WS \qquad (1)$$

Table 3.2 shows a preliminary translation of the most important factors in all missions into design requirements. These design requirements were the base of our initial studies and used to maximize the total score.

Table 3.2: Mission requirements and translation into preliminary design requirements.

Mission Requirement	Design Translation
Minimize Empty Weight	Minimal Airframe Structure and Propulsion Weight
Minimize Perpendicular Wing Span	Balance of Payload with Structure; Efficient Aerodynamics
Maximize Speed	Efficient Propulsion System; Efficient Aerodynamics
Maximize Payload Capacity	Efficient Weight Analysis

A culmination of these alternatives and their decision matrix major factors can be seen in Table 3.3. The decision matrices were judged on a scale from 0 to 5 where 0 was inferior and 5 was superior. Each major decision factor was given a weight based on its importance to the mission profile and then analyzed. The factor with the highest net score was selected as shown in red.

Table 3.3: Conceptual Design Matrix of Alternatives.

Components	Alternatives			Decision Matrix Major Factors
Wing Location	High	Middle	Low	Payload Interference, Stability
Wing Arrangement	Straight	Swept	Biplane	Manufacturability, Aerodynamics
Empennage Configuration	Conventional	T-Tail	Plus	Weight, Size, Strength, Interference
Number of Booms	One	Two	Internal	Torsional Resistance, Size, Strength
Landing Gear Configuration	Skids	Tricycle	Tail Dragger	Strength, Manufacturability
Passenger Loading	Top	Side	Back	Loading Time, Manufacturability
Cargo Location	Behind	Below		CG Location, Manufacturability
Number of Motors	One	Two	Multiple	Weight, Efficiency, Thurst

The trade studies began by keeping the perpendicular wingtip distance at a minimum, while maximizing the number of passengers and amount of cargo that could be carried by the aircraft. The goal of this study was to find an effective balance to maximize the total score while adjusting to the budgeted time of the team. The weight of the plane was designed to be below 4 lbs. with a desired aspect ratio of 6. This aspect ratio was chosen from previous studies for a high speed, highly maneuverable aircraft. These were used to begin our calculations, in which a scoring sensitivity analysis was created to analyze this year's mission profile. Since the scores of missions 2 and 3 are a factor of the best team's scores, we assume our plane is built to achieve this maximum. The Total Mission Score was analyzed from a baseline score. This baseline was determined by our team from past experience and initial aircraft sizing. These conclusions can be found in Figure 3.1.

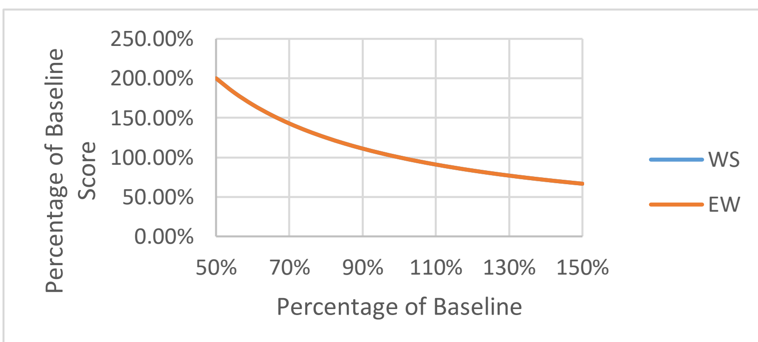


Figure 3.1: Score Sensitivity Analysis

After an initial score sensitivity analysis, it was proven that both factors in the RAC are equally impactful. Through the team's analysis, minimizing the perpendicular wingspan of the aircraft was chosen as our primary factor. Minimizing this factor and balancing the aircraft in terms of sound aerodynamics and competitive capacity would yield a lower empty weight as well, thus minimizing RAC and maximizing the Total Score. Using a desired wing loading of 28 oz/ft^2 from previous structural manufacturing experience, the calculated wing span was approximately 44", with a chord length of 7.4" and a wetted surface area of 329 in^2. From this data, and an estimated wind speed of 10 m/s (from previous experiences), the Reynolds number is found to be 145,000, using standard air measurements. Airfoils are being analyzed using Airfoil Investigation Database; this site uses XFOIL to analyze crucial features of airfoils under different Reynolds numbers. Investigation into the usage of Vortex Lattice Method is also under way. Currently two software are being compared in terms of the team's experience and budgeted time; the two software include Athena Vortex Lattice and OpenVSP.

4. MANUFACTURING PLAN

Our manufacturing plan consists of 5 subassemblies; fuselage, empennage, wings, landing gear, and passenger compartment. Special consideration must be made for each because of the constraints of LRUs defined in the mission profile. The fuselage will be a rectangular prism made from laser cut balsa sheets, with plywood or carbon fiber reinforcement beams in high-load areas. The batteries and motor will be contained within a narrowing nose piece integrated onto the front of the fuselage. The batteries and receiver will be secured using an elastic hook restraint system, and the motor will be screw-mounted on a 3D printed mount, with a hatch in the nose for easy accessibility. The passenger compartment will contain 2 rows of "seats" made from fabric with a drawstring restraint system, with the payload compartment directly underneath. The passenger bay will be accessible through a hatch on the top of the fuselage, while the payload bay will be accessed through the side. The empennage will also be made of reinforced balsa or plywood for the superstructure, with flat sections of laser cut balsa for paneling and the tail surfaces. The wings will be made of laser cut balsa airfoil ribs, with carbon fiber stringers forming the main spar for structural support and balsa wood stringers for MonoKote adhesion. MonoKote is a brand of heat shrink plastic designed for covering hobby aircraft. A piece of molded balsa will form the leading edge of the airfoil and provide an initial fluid contact surface and structural rigidity. The control surfaces on both the wings and the tail will be attached using 3D printed hinges to allow easy exchanges with new components. Servos will be contained within 3D printed mounts, again to allow for easy replacement. The front landing gear will be made from formed carbon fiber struts, with a solid axle to connect two plastic and rubber wheels. The wheels will be secured to the axle with screw-tightened collars to allow for easy replacement. The rear gear will be a simple tail dragger made from molded carbon fiber or 3D printed plastic.

5. TESTING

Testing of the aircraft will be broken into component, ground, and flight testing. Each test is designed to ensure all desired characteristics of the aircraft are met and maintained. Through accurate testing, the team can determine any issues and adapt accordingly. In Table 5.1, a breakdown of this testing data is shown in the form of a test plan that the team will use when designing, manufacturing, and flying.

Table 5.1: Test Plan

Phase	Factor	Test Approach	Goal
Component	Motor and Prop	Motor test stand	Check efficiency and static thrust
	Battery	Motor test stand	Check current draw, voltage, and battery life
	Passenger Restraint	Simulate load stability by hand	Conclude restraints are working and strong
Ground	Center of Gravity	Wingtip test	Determine CG is in team's desired location
	Control Surfaces	Use all controls on controller	Conclude all functions are working properly
	Secure LRUs	Apply pressure to LRUs	Conclude LRUs and fasteners are not loose
Flight	Speed	Stopwatch for timing	Determine aircraft lap time
	Stability	Visual cues and pilot's experience	Determine flight characteristics of aircraft
	Takeoff Distance	Use team member to mark takeoff	Approximate takeoff distance

University of California, Irvine

Henry Samueli | School of Engineering

Textron/Raytheon
AIAA

2017-2018
Design/Build/Fly
Proposal

Executive Summary

This proposal summarizes the progress of the UCI Design/Build/Fly (DBF) team's efforts in the design, analysis, and manufacturing of their aircraft for entry in the 2017-2018 AIAA Design/Build/Fly competition. This year's objective is to design a dual purpose regional and business aircraft capable of carrying both passengers (rubber balls) and payload (cuboid blocks) in separate compartments, while demonstrating serviceability through Line Replaceable Units (LRUs). The goal of the UCI DBF team is to design an aircraft that will complete all mission requirements and obtain the best total score. Total score is composed of Written Report Score (WRS), Total Mission Score (TMS), and Rated Aircraft Cost (RAC), with RAC being the most sensitive parameter of the total score according to the sensitivity analysis.

The initial scoring analysis points the design towards a low empty weight and short wingspan to maximize the total score. The team has explored monoplane, biplane, and flying wing configurations to determine the best configuration for the initial design. Based on the team's score analysis and flight condition considerations, a monoplane configuration with a short wingspan and small number of passengers has been selected for the preliminary design. After the initial design, the team will focus on components' detailed designs. LRU, passenger restraint, and payload restraint designs will flow through the manufacturing loop which consists of development, testing and optimization.

Management Summary

The UCI team employs a hierarchical structure (Figure 1) that promotes collaboration and accountability and is composed of management, team leads, and general members. The chief aerodynamics engineer is responsible for aerodynamic design and sizing of the aircraft. The chief structural engineer aids in conceptual design and focuses on oversight of the structural design and component manufacturing. The project manager sets milestones (Figure 2), delegates tasks to each sub-team, and manages the budget. Decisions made by the chief engineers and project manager are passed down to sub-team leads, who are responsible for creating parts in adherence to prototype milestones, utilizing various manufacturing techniques and help from general members. Propulsion team members assist the chief aerodynamics engineer in the selection of fine-tuned

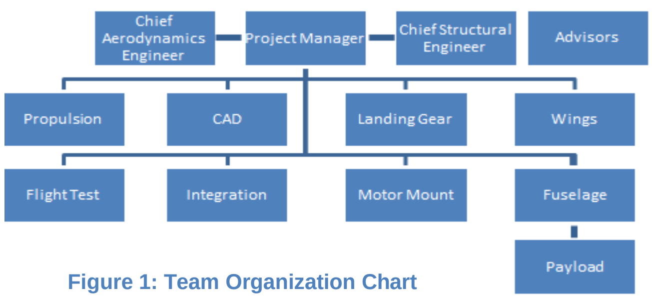


Figure 1: Team Organization Chart

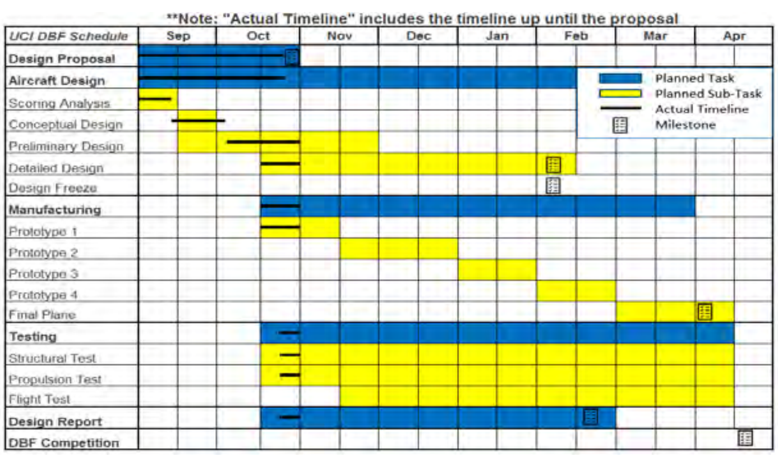


Figure 2: Gantt Chart with Major Milestones

propulsion system solutions, by testing many battery, motor, and propeller combinations. The Flight Test team maintains test cards, organizes, and carries out the test flights used to validate final mission performance. The CAD team documents designs and uses Solidworks to create drawings and 3-D models for the plane. Landing gear, motor mount, fuselage, wings, and payload make up the structurally focused teams that design and manufacture key components such as the airplane's structural elements, LRUs, and payload restraints. Sub-team members also assist by planning and conducting component tests and integrating subassemblies into the final aircraft.

Type	Summary	Percentage of Total (%)	Cost ($)
Electronics	Motors, ESCs, Batteries, Gyros	32	1790
Fabrication Materials	Composites, Balsa wood, Foam	25	1420
Transportation	1 passenger van; Gasoline	17	960
Tooling	Laser cutting fees, Drills, Cutting tools	14	790
Housing	1 hotel room, 4 nights, 5 people	9	500
Off the Shelf Components	Landing gear wheels, Push rods, Propellers	3	175
		Total Cost	$5,635

Figure 3: Budget Breakdown

The budget (Figure 3) intends to account for essential project costs and prioritizes aircraft development. UCI's DBF Team has chosen to bring only five key members and devote 74% of its financial resources towards the tools, electronics, and materials needed for prototyping. The amount of materials necessary for five prototypes and two additional plane builds are taken into account in the team's estimations. Devoting a large amount of financial resources to development allows the team to optimize the aircraft within budget constraints.

Conceptual Design Approach

Total mission score for this year's competition is the sum of three flight mission scores; however, an unscored ground mission must be completed prior to attempting missions 2 and 3. The aircraft must

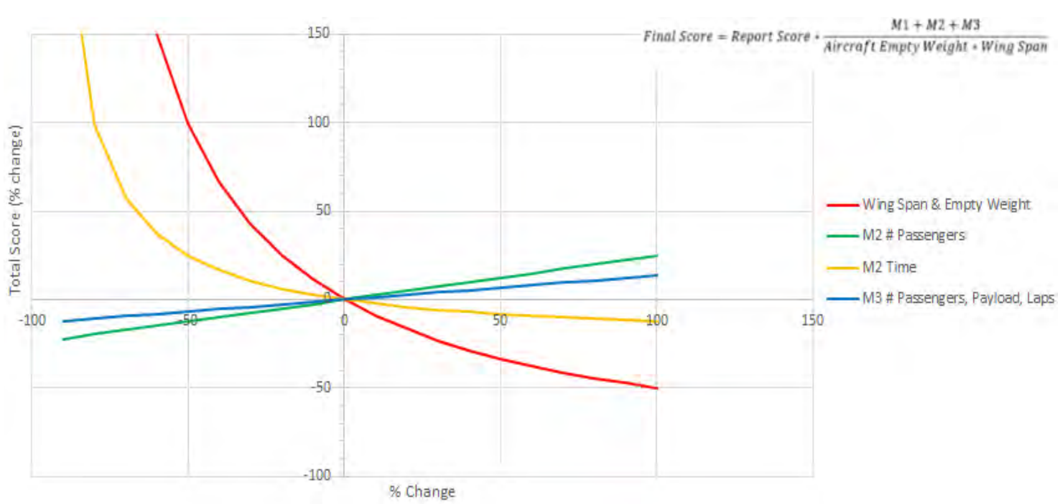


Figure 4: Score sensitivity analysis normalized in percent change from baseline design

take off within a field length of 150 feet for all flight missions. Mission 1, *Aircraft Mission Staging*: fly three laps empty within five minutes. Mission 2, *Short Haul of Max Passengers*: fly three laps with a declared amount of passengers within five minutes. Mission 3, *Long Haul of Passengers and Payload*: transport a declared quantity of passengers with individual restraint systems and payload blocks stored in the payload bay(s) for as many laps as possible within ten minutes. Ground Mission, *Field and Depot LRU Replacement*: remove and replace two line replacement units chosen with rolls of a six-sided die within eight minutes.

The design is driven by a combination of constraints provided in the rules and the most sensitive parameters in the scoring equation: wingspan and empty weight. In addition to the airframe, empty weight is affected by the payload accommodations required by Mission 2 and 3, the ground mission LRU's, and the propulsion system. The propulsion system is constrained by the flight time limit for a fully loaded aircraft in Mission 2. A margin accounts for efficiency losses and historical wind speeds in Wichita. When normalized, the sensitivity analysis (Figure 4) reveals that the aircraft should be optimized for RAC rather than total mission score; for this reason, the propulsion is not optimized for any additional performance.

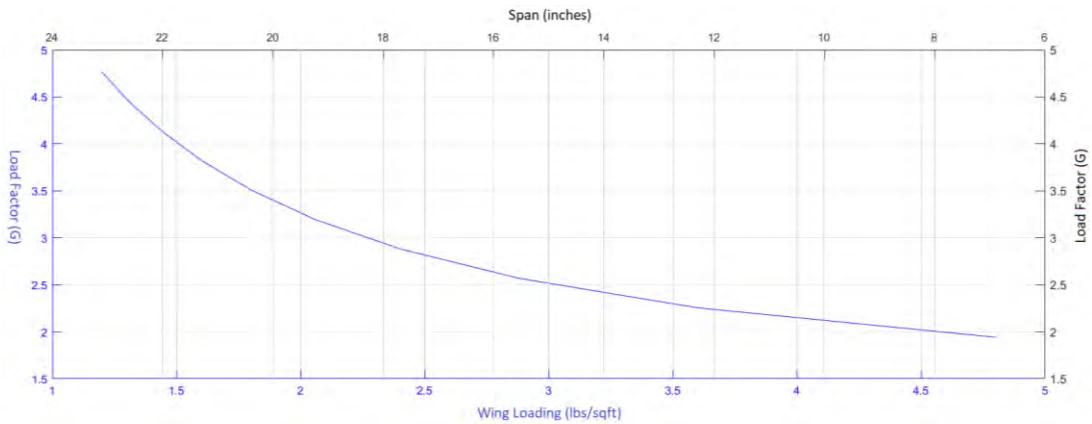


Figure 5: Load Factor vs. Wing Loading due to 10 ft/s vertical gust. Fixed values: Weight: 1 lb., Chord: 5 inches

Figure 5 shows an inversely proportional trend between wing loading and load factor, demonstrating that a higher wing loading is more effective at negating gusts. In the figure, chord length has been set by an expected Reynolds number of 100,000 with a BA9 airfoil. This airfoil is a preliminary choice and performs well at low Reynolds numbers. Wing area is varied by changing span to demonstrate how increased wing loading dampens the effect of wind; however, it should be noted that higher wing loading in Figure 5 results from decreasing the span. Since short span designs decrease roll inertia, smaller ailerons can be utilized to offset the high roll sensitivity.

Figure 6: Concept Sketch

For the initial design a biplane was considered; however, this configuration nearly halves the wing loading for a fixed span. Figure 5 shows that this lower wing loading will cause the plane to be more susceptible to wind. A flying wing is also being considered for future iterations because of its decreased wetted area; however, on a small scale it may be difficult to find an airfoil with sufficient performance and chord thickness to store payload. A conventional design was chosen for the first prototype (Figure 6) since the focus of the initial design is to test the shortest possible span. This configuration will be an effective benchmark during flight tests due to its familiar handling qualities and ability to use a removable wing mount to test varying wing sizes.

Manufacturing Plan

Figure 7: The feedback loop each component must follow throughout the manufacturing process.

Integration is embedded in the design of components and is the final step of a component's manufacturing flow. The components that flow through Figure 7 are either formally prototyped or rapidly prototyped. A rapid prototype is overbuilt to withstand expected loads during testing as a proof of concept. In this case, ease of manufacturing, strength, and time are prioritized. Technologies, such as CNC machining and 3D printing, and materials, such as foam and built-up balsa structures, are essential for rapid prototyping. Once a rapid prototype's design is validated, it is succeeded by a formal prototype. These prioritize reliability and lightweight materials over manufacturing feasibility due to the scoring sensitivity of weight. Minimal materials and intricate manufacturing steps such as laser cut balsa and laid up composites are used at this stage. The component undergoes an optimization process which consists of reducing its weight until testing shows that it no longer meets the design requirements. The component is finalized when it arrives at the end of this optimization process.

Test Planning

A strict manufacturing, testing, and integration schedule is maintained for each individual component and the entire aircraft. Many components are tested statically in order to determine unknown variables and discover limitations. Alongside the aircraft design, a flight test plan is developed to outline test objectives, flight parameters, and procedures. The main purpose of the flight test is to evaluate and validate the aircraft's overall performance. The test plan streamlines flight tests and facilitates the creation of detailed logs for documentation and development of future prototypes.

Current static tests focus on the impact of various battery cell configurations at low voltages on propulsion components. Concurrently, prototype fuselages and short wings undergo thorough load testing to yield greater insight into structural loads and the effectiveness of manufacturing techniques. As the team explores various component designs with rapid prototyping, testing will aid the overall aircraft design development and allow validation of components before their integration onto the final optimized design.

2018 AIAA Design/Build/Fly Competition

Design Proposal

MACH, University of Michigan

31 October 2017

1. EXECUTIVE SUMMARY

1.1 Objective Statement

MACH is a University of Michigan student-run design team participating in the American Institute of Aeronautics and Astronautics Design/Build/Fly (AIAA DBF) competition. MACH's primary objective for the 2017-18 competition cycle is to design, construct, and test a vehicle that performs within the top 20% of competition aircraft.

1.2 Planned Approach to Complete Objectives

With the initial scoring analysis and conceptual design of the aircraft complete, the team is now focused on the preliminary design. Next an internal Preliminary Design Review will take place with students and faculty advisors. The team will then commence the detail design process, followed by an external Critical Design Review with corporate sponsors. The planned timing for the first test flight is the beginning of the new year, which will allow for ample time to further refine the design prior to competition.

2. MANAGEMENT SUMMARY

2.1 Description of Organization

To establish organization within the team, we selected a tiered leadership structure as shown in **Figure 1**. The organization is led by the Team Captain, who is responsible for organizing and directing the entire team. The Chief Engineer, Build Manager, and Business Manager are responsible for overseeing design decisions, organizing the construction of the aircraft, and managing the budget and sponsor relations, respectively. In addition, the team is broken up into a number of technical sub-teams each managed by a designated lead. The Propulsion Team is responsible for selecting the propulsion and control system using simulation software such as Motocalc and Ecalc. The Aerodynamics Team is primarily responsible for wing, empennage, and control surface design and optimization through the use of MATLAB, XFoil, Athena Vortex Lattice, and XFLR5. The Structures Team is responsible for fuselage, wing structure, and landing gear design, as well as the complete CAD of the aircraft using Solidworks. The Special Structures Team is responsible for payload placement and the passenger constraint system, and will work closely with the structures team to integrate their design seamlessly into the full system. The milestone chart shown in **Figure 2** was produced to ensure the team will meet major deadlines and maintain desired progress. We remain on schedule to reach our goals for both the design report and the fly-off.

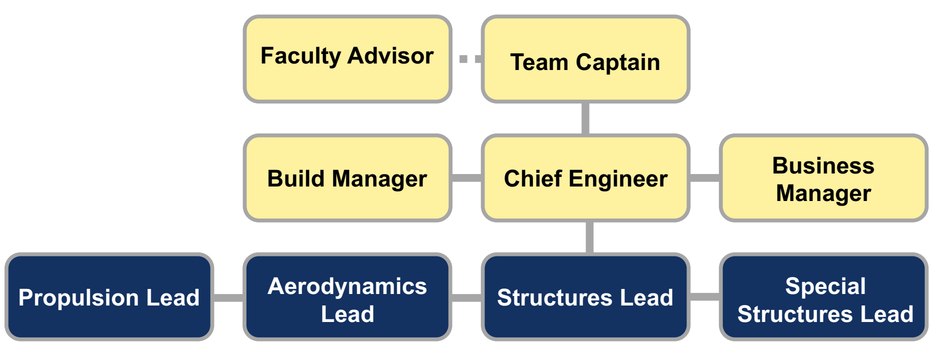


Figure 1: Team Leadership Structure and Membership

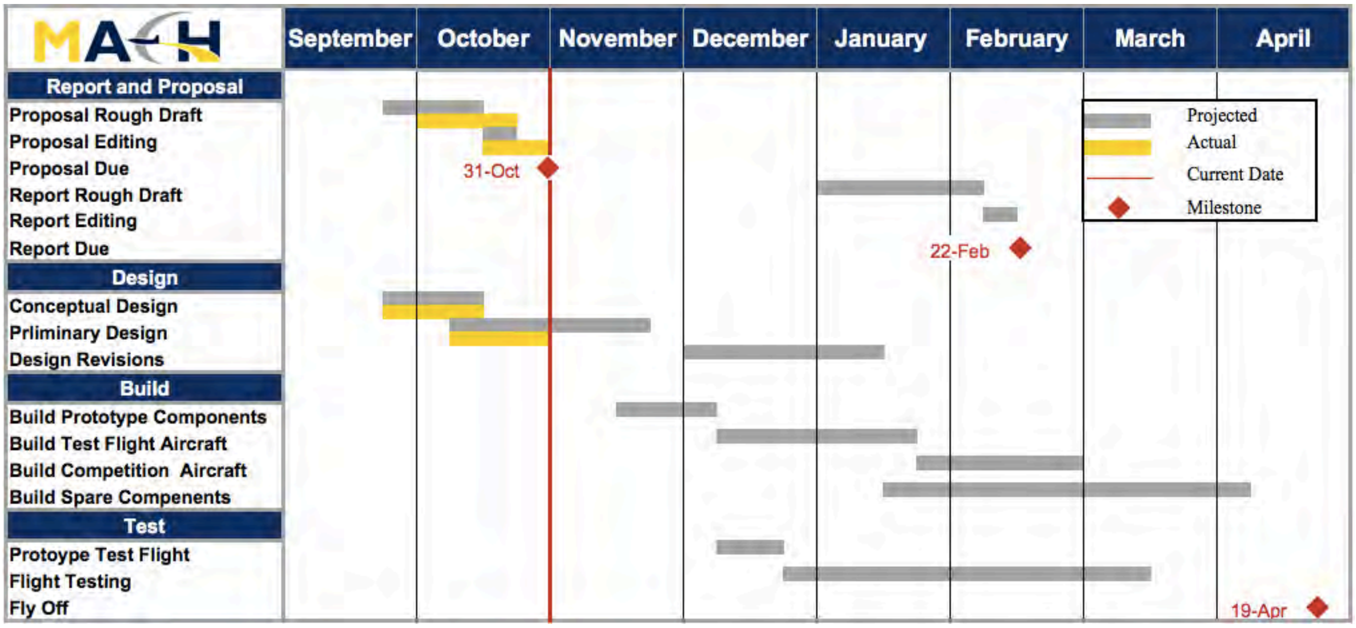


Figure 2: Current Milestone Chart Showing Projected and Actual Progress

2.2 Budget

MACH's 2017-18 budget totals $15,000 and is broken down into categories of construction materials, hardware, electronics, competition expenses, and networking. As shown in **Table 1**, the largest expense will be transportation and lodging for the fly-off competition. MACH receives generous financial support from Lockheed Martin and the University of Michigan Department of Aerospace Engineering to meet our budgetary needs.

MACH 2017-18 Budget	
Construction Materials	**$ 2,285**
Hardware/Tools	**$ 500**
Electronics/Propulsion	**$ 2,200**
AIAA DBF Competition	**$ 7,600**
Networking/Recruiting	**$ 855**
Reserves/Incidentals	**$ 1,560**
Total	**$ 15,000**

Table 1: 2017-18 Budget Totals and Breakdown

3 CONCEPTUAL DESIGN APPROACH

3.1 Mission Requirements

The 2017-18 DBF competition consists of three flight missions and one ground mission. Mission 1 requires the aircraft fly three laps within five minutes carrying no passengers or payload. Mission 2 consists of flying three laps within five minutes while carrying as many passengers as the team desires with no payload. Mission 3 consists of a ten-minute flight window, where the aircraft will fly as many laps as possible while carrying at least half the passengers from mission 2, with the option of carrying additional payload blocks. The payload blocks must be placed either behind and or below the passengers. The mission 2 and 3 scores will also be normalized by the maximum scores obtained by any team for the respective missions. Therefore, the team must develop a way to estimate the maximum score achieved for each mission to obtain a weighted score for prospective designs.

The ground mission must be completed prior to attempting mission 2. The ground mission is broken into two stages, totaling 8 minutes. The first stage is the Field Line Replaceable Unit (LRU) replacement, where a specified LRU and tools must start within the aircraft's payload bay, and must be replaced within 3 minutes. The second stage is the Depot LRU replacement. In this stage, the tools and LRU will be placed in the designated area, and then be replaced in the remaining time. Following the replacement of both LRUs, a functional demonstration of the replaced LRUs must be conducted. This will require modular design that is easily serviceable.

The overall score is a product of the overall mission score and report score, divided by the Rated Aircraft Cost (RAC), the product of the empty weight and wingspan of the aircraft.

3.2 Preliminary Design

The conceptual design process was focused on obtaining the most optimal aircraft to successfully accomplish all flight missions and to maximize the overall score. Therefore, the focus was on minimizing the wingspan and empty weight, and therefore RAC, while maximizing the number of passengers carried by the aircraft. Each major design factor was quantified and prioritized in a decision matrix to decide the overall aircraft configuration. The team ultimately decided to select a twin-engine biplane design as seen in **Figure 3**. The biplane was chosen as it would have a smaller wingspan compared to a monoplane. The decrease in wingspan has a larger effect on the RAC than the slight increase in weight due to the additional wing.

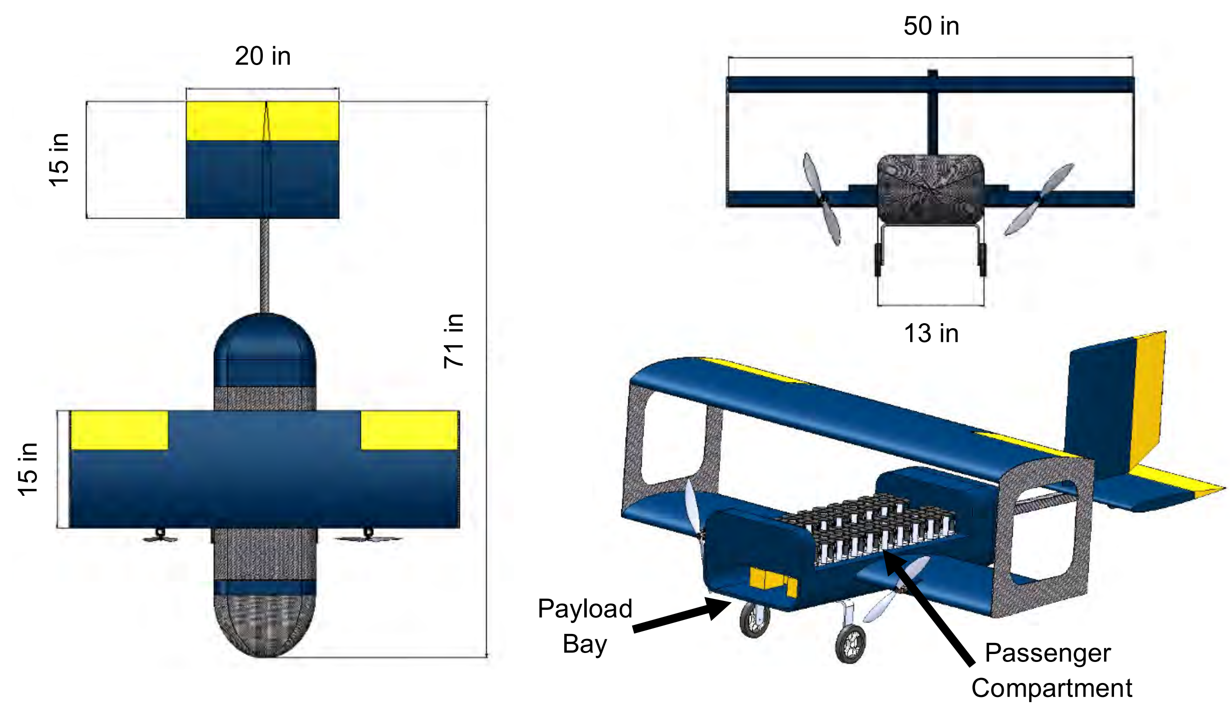


Figure 3: Preliminary Aircraft Design

Based on the scoring and sensitivity analysis discussed in Section 3.3, we determined the maximum passenger count should be 40. A two-wide passenger bay with 20 rows would be difficult to implement because of its length, therefore the passengers will sit four-wide in 10 rows with a centered isle. Each passenger will be restrained in a cage-style 'seat' with a slit rubber top. Each ball will be inserted from above through the rubber top, and sit on a compressible foam base which will hold any sized ball tightly against the upper rubber surface. This design was chosen due to its loading efficiency, as all 40 passengers will need to be loaded in 5 minutes.

Because our fuselage width will be determined by four ball diameters and a two-inch aisle, a twin-engine wing-mounted propulsion system was selected to avoid blocking the prop-wash.

3.3 Sensitivity Analysis

To determine which design parameters had the most effect on the overall score in the scoring function, baseline parameter values were selected and varied by 10% intervals. **Figure 4** shows the results of this analysis and show that the empty weight and the wingspan have the largest effect on the overall score, followed by the number of passengers carried.

These results were used to study the effects of various design parameters together on both flight mission scores and RAC. A scoring analysis was conducted which considered factors such as varying passenger count, wingspan, and payload, structural and propulsion weight, as well as finite wing effects. The results of this analysis are shown in **Figure 5**. From this data, it was determined that the aircraft should be designed with a wingspan of 50 inches, aspect ratio of 3.3, maximum capacity of 40 passengers, and an estimated empty weight of 6.6 pounds.

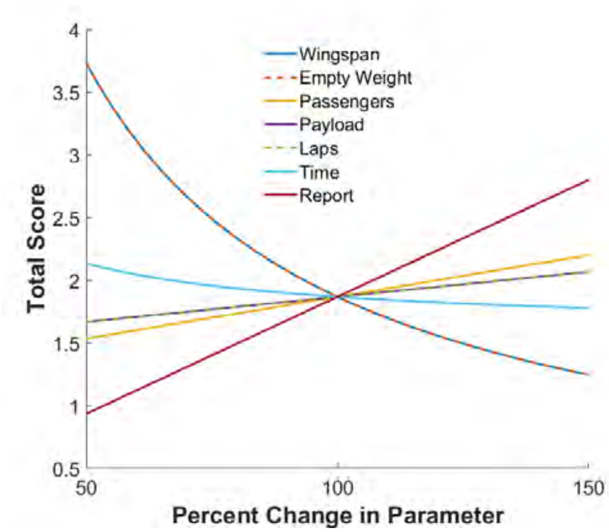


Figure 4: Sensitivity Analysis

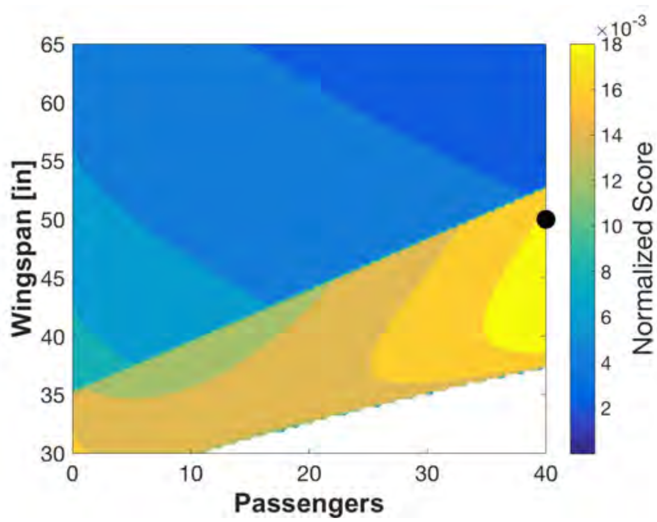


Figure 5: Scoring Analysis Results

4. MANUFACTURING PLAN

4.1 Preliminary Manufacturing Flow

In the coming weeks, the team will begin prototyping the passenger restraint system to ensure its effectiveness. Following our critical design review at the end of November, we will begin assembling the wings. The wing consists of a rib and spar construction with a composite leading edge, and an Ultrakote skin. Due to its size and complexity, the wing sections will be the first components assembled. Following the completion of the wing, the fuselage with landing gear and tail will be constructed in tandem. Finally, the full vehicle will be assembled with support structures, motors and electronics. A detailed manufacturing flow chart can be seen in **Figure 6**.

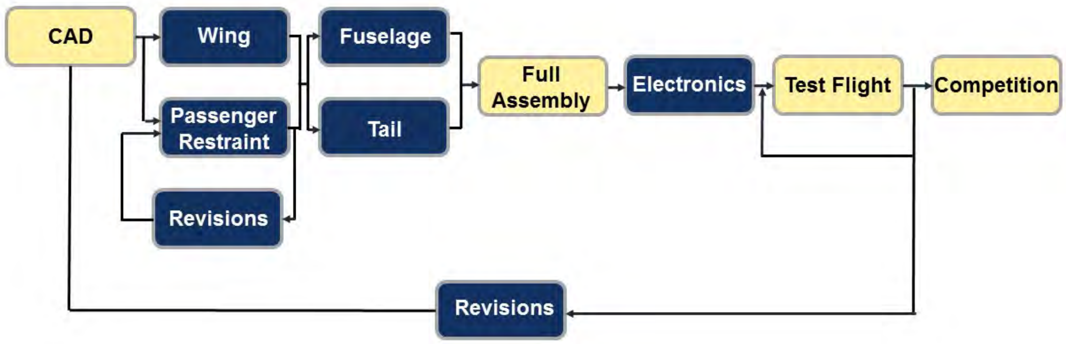


Figure 6: Manufacturing Flow

4.2 Processes and Technologies Required

A number of technologies and skillsets will be required for our construction methods. We plan to utilize a CNC router to machine wax molds for composite layups. A vacuum bagging technique will be used to ensure the proper shape is held during the layup's cure cycle. Additionally, a laser cutter will allow the team to accurately and efficiently produce intricate constructions elements. A spot welder will be used to attach the connecting tabs to our battery cells for the production of custom battery packs. Work will be performed almost exclusively in a dedicated team workspace equipped with workbenches, stock materials, tools, and electrical diagnostic instruments.

5. TEST PLANNING

5.1 Component and Ground Test Plan

MACH plans to perform extensive ground testing throughout the design and construction processes. Once the motors and propellers are selected, their performance will be tested using a static thrust stand to verify the results obtained by the Propulsion Team. Following the completion of the first prototype, we will conduct wing tip load tests, flight controls checks, landing gear load tests, and timed passenger loading tests.

5.2 Flight Test Plan

Flight testing will take place at Flying Pilgrim's RC field in Superior Township, Michigan. The aircraft will be evaluated on mission performance through a series of flight tests represented in **Table 2**. For each test flight, MACH will begin with a Proof of Concept Test to verify the aircraft's aerodynamic capabilities. Then, the demonstration flight test will be conducted, followed by tests to determine maximum passenger and payload capabilities. The final test flight will consist of flying all three flight missions to better estimate our aircraft's performance under competition conditions. Following each test session, MACH will analyze performance and make any necessary design changes.

Flight Test Plan	
Flight Test Number	**Objective**
1	Proof of Concept Test
2	Demonstration Flight Test
3	Max Passenger Test
4	Long Haul Test
5	Full Competition Test

Table 2: Winter 2018 Flight Test Plan

LUFTGOPHER.

AIAA Design/Build/Fly 2018

University of Minnesota - Team FLY-U-MAH

Project Proposal

Executive Summary

The objective of the University of Minnesota's Fly-U-Mah project team in response to the American Institute of Aeronautics and Astronautics' (AIAA) 2017-2018 Design, Build, Fly Competition is to design, construct, and demonstrate the flight capabilities of a dual purpose regional and business aircraft. We will design our aircraft to maximize scoring opportunities by maximizing both passengers and cargo carried while maintaining high speeds, a low weight, and safe operation throughout each of the four missions.

To achieve our goal of constructing a competition-ready aircraft, our team will organize and divide into sub teams, each of which will iterate through the engineering design process. Each team will first define both the problem at hand and the constraints on possible solutions. Subsequent steps then include conceptualizing the problem, determining an approach, building, and testing. We will improve our solution by iterating through this process again, each time with critical improvements, until our solution meets the objective and is within the constraints of this year's competition rules.

Management Summary

The organization for this year's team reflects last year's team structure. We currently have five returning members, one of whom is leading the team, and six new members. All members are undergraduate students, and we are still actively recruiting. Our team receives support from our faculty advisor John Weyrauch and our previous team lead Nikolas Pardoe. The team has been divided into five sub teams, which each meet weekly. Full-team meetings are also weekly; there, sub teams provide updates and collaborate on the project.

Sub Team Name	Primary Responsibilities	Desirable Skillsets
Aerodynamic Design and Sizing	Direct general analysis and design, component integration.	Understanding of RC aircraft and mechanics of flight, skill with computational tools.
Structures and Integration	Fabricate structural components, integrate systems built by other sub teams.	Prototype/fabrication experience, knowledge of building materials, shop experience.
Electronics and Propulsion	Select, design, and assess electric propulsion and control systems.	Understanding of electrical systems, motors, batteries, controls, and power consumption.
3D Modeling and Simulation	Create 3D models for design/ visualization, conduct aerodynamic and structural simulations.	Experience modeling parts and assemblies in CAD programs, computer simulation skills.
3D Printing	Identify, model, print, and test components that benefit from 3D printing.	Modeling and 3D printing experience, understanding of material properties and stress testing.

Table 1. Table of Sub Team Divisions and Project Roles

The University of Minnesota's Design Build Fly project team is fully funded by the University's AIAA Student Chapter. Most of the funding comes in the form of grants and other University sponsored funding. Our goal is to effectively use the money that has been provided to our project to reduce spending waste and stay under budget. Our budget has been created by reviewing spending from the previous competition and adjusting the budget to fit our plans for this year. The budget has been divided into four sections: Build materials (Competition Aircraft), Electronics (Competition Aircraft), Travel Expenses, and Estimated Prototype costs.

#	Item	Price per	Qnty	Amount		
Build materials						
1	Aircraft Plywood	$30.00	3	$90.00		
2	BirchWood	$30.00	3	$90.00		
3	Competition Grade Balsa (A&B)	$20.00	5	$100.00		
4	Formular - 150 Foam	$24.77	3	$74.31		
5	Fiberglass	$30.00	5	$150.00		
6	Carbon fiber cloth (per yard)	$150.00	6	$900.00		
7	Epoxy resin (aircraft grade)	$99.00	3	$297.00		
8	Epoxy hardener	$48.00	3	$144.00		
9	Carbon fiber fuselage spar	$55.00	4	$220.00		
10	Carbon wing spar	$20.00	6	$120.00		
11	Carbon pushrods	$3.00	5	$15.00		
12	Nylon Clevises	$2.25	3	$6.75		
13	Carbon reinforced 3d printer filament roll	$40.00	3	$120.00		
14	Hinge parts	$3.00	6	$18.00		
15	Landing gear	$20.00	2	$40.00		
16	Propellers	$12.00	8	$96.00		
Electronics						
17	NiMh Battery	$30.00	5	$150.00		
18	Rx battery	$15.00	3	$45.00		
19	Servos	$16.00	5	$80.00		
20	Servo Extensions	$6.00	5	$30.00		
21	Motor	$85.00	3	$255.00		
22	ESC	$40.00	3	$120.00		
23	Receivers	$30.00	3	$90.00		
24	Gyro stabilization module	$30.00	3	$90.00		
General materials:						
1	Misc Building Supplies and Materials	$300.00	1	$300.00		
			Total:	$3,641.06 ->		$3,641.06
Travel:						
2	University van weekly rental	$304.00	2	$608.00		
3	Fuel	$800.00	2	$1,600.00		
4	Lodging (4 nights, 4 rooms)	$2,140.00	1	$2,140.00		
			Total:	$4,348.00 ->		$4,348.00
Prototypes:						
1	Initial Design Exploration Prototype		1	1827.83		1827.83
2	Advanced Technology Prototype		1	2796.6		2796.6
					Grand Total:	$12,613.49
					Other Income:	$9,613.49
					Grant Request	$3,000.00

Table 3. Estimated Budget for Project Construction Based on Conceptual Design and Travel Expenses

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
1	Project Conception and Initiation					
1.1	Evaluate Rules and Maximize Scoring Opportunities		9/21/17	10/5/17	14	100%
1.1.1	Conceptual Design of Cargo and Passenger Bays		9/21/17	10/7/17	16	100%
1.2	Conceptual Wing/Airfoil/Tail Design		10/12/17	10/24/17	12	100%
1.3	Estimate Propulsion System Requirements		11/15/17	11/30/17	15	0%
1.4	Preliminary CAD Model of Major Components		10/21/2017	11/1/17	10	75%
1.5	Mock-Units of Cargo and Passenger Bays		11/1/17	12/15/17	44	0%
1.6	**Project Proposal (Major Milestone)**		10/7/17	10/31/17	24	100%
2	Project Definition and Planning					
2.1	Preliminary Design of Cargo and Passenger Bays (Fuselage)		11/2/17	12/7/17	35	0%
2.2	Preliminary Wing/Airfoil/Tail Design		11/2/17	12/15/17	43	0%
2.3	Preliminary Electronics Selection		11/2/17	12/15/17	43	0%
2.4	Preliminary Materials Selection		11/2/17	12/7/17	35	0%
2.5	**Preliminary Complete Design (Major Milestone)**		11/9/17	12/15/17	36	0%
3	Project Revision, Testing, Documentation					
3.1	Initial Computer Aided Fluid and Stress Analysis		12/15/17	1/16/18	31	0%
3.2	Aerodynamic Design Revisions and Improvements		1/16/18	2/16/18	30	0%
3.3	**Final Aircraft Design (Major Milestone)**		1/21/18	3/1/18	40	0%
3.4	Final Electronics Selection		1/21/18	3/8/18	47	0%
3.5	Final Materials Selection		1/21/18	3/1/18	40	0%
3.6	**Design Report (Major Milestone)**		1/16/18	2/22/18	36	0%
4	Project Construction and Performance					
4.1	Construction Phase 1		1/16/18	2/28	42	0%
4.2	**Test Flights Phase 1 (Major Milestone)**		3/1/18	3/14	13	0%
4.3	Project Construction, Repairs, and Modifications		2/1/18	4/12/18	71	0%
4.4	Test Flight Flights Phase 2		3/21	4/1/18	10	0%
4.5	Competition/Fly-off		4/19/18	4/22/18	3	0%

Table 2. Tentative Project Schedule and Major Milestones

Conceptual Design Approach

The overall goal this year is to create a serviceable regional and business aircraft that can maximize flight capabilities such as speed and endurance, while minimizing empty aircraft weight and maximizing passengers and cargo carried. The aircraft must also have field LRUs (Line Replaceable Unit) that are replaceable within 3 minutes and depot LRUs that are replaceable within 5 minutes, as described in the rules. Thorough design will ensure that these items are quickly replaceable and maintain the aircraft's structural integrity.

Conceptually, our aircraft must maximize passengers and cargo per unit volume. Our approach is to design from the inside out, starting with our cargo and passenger bays. We found that the most space-efficient passenger bay configuration was four passengers per row, resulting in a passenger density of 1 passenger per $10in^3$. The cargo blocks are most dense with dimensions of 5-in x 2-in x 2-in (Length x width x height). With this information, we can optimize the passenger and cargo bays to minimize fuselage dimensions. We also consider that the LRUs and any tools for the ground mission must be stored inside the cargo bay prior to the start of the mission.

Our next step was to examine the trade-off between aircraft speed and payload capability. While analyzing the scoring formula, we found that flight missions two and three are heavily influenced by the number of passengers carried and each ounce of cargo. We determined it more effective to carry more weight and passengers, since one more ounce of payload or one additional passenger is mathematically equivalent to one entire lap completed in flight mission three. This will require a large motor and power system to achieve speeds necessary for flight. We are optimistic that our power system will scale up well, as battery weight was a concern last year.

Our next design consideration regards the RAC (Rated Aircraft Cost), which is the maximum empty weight multiplied by the aircraft's wingspan. To decrease our wingspan and empty weight, our team will utilize advanced materials, USU Aero Lab's MachUp and other aerodynamic calculators, and consider less-traditional designs such as a biplane.

Figure 1. 3D Model Render of Conceptual Design Major Components

Manufacturing Plan

This year we will use more advanced construction materials like carbon fiber to improve performance, so our construction methods and technology need to be altered, but the general flow of our manufacturing plan remains the same.

As we create an overall design, the team will also plan the materials and construction method for each aircraft component, particularly whether it should be 3D printed. Once we have a satisfactory design and are ready to begin construction, we will purchase any necessary tools and materials not found in last year's remaining inventory. Responsibility for various components will be delegated among all team members, primarily members of the Structures/Integration and 3D Printing sub teams. Throughout the build process, all members will meet frequently to fix integration issues and make design alterations.

Assembly and component manufacture will begin with the inner structures of the fuselage and work outwards. For the fuselage, we plan to laser-cut a load-bearing plywood frame that accepts cargo items and attaches the rest of the aircraft. We will next laser-cut balsa ribs for the wings and tail. We prefer laser-cutting over traditional shop tools for its speed and accuracy in cutting thin, two-dimensional parts. Carbon-fiber spars will support the wings and tail assembly. The wings and tail will be attached to the fuselage, then finished with MonoKote.

Finally, the fuselage will be covered a composite shell that reinforces the plywood frame. Previously, we have done fiberglass layups on foam molds, removing the mold after the layup cures. This year we plan to experiment with laying directly onto the airframe, which should reduce integration issues and increase strength. Both fiberglass and carbon fiber are being considered for this process. 3D-printed components including the engine mount, quick-replaceable connectors, and other small, custom parts will be completed last. 3D printing offers quick, accessible production of complex parts. This year we plan to investigate new filament types and multiple printer models to produce the most effective parts.

Test Planning

The UAV must demonstrate flight capabilities as well as safe operation. To support our design process and determine if the UAV is competition ready, a series of tests will be performed. 3D models of our aircraft will be created in PTC Creo and fluid analysis will be conducted using ANSYS prior to building our final competition aircraft so that optimization and changes can be made. After computer simulations are completed, physical tests will be conducted on our prototypes and competition aircraft. Our component and ground test plan is detailed in the table below:

Test Category	Description	Purpose
Flight Position Tests	Wing tip load tests, CG tests for each of the 3 flight mission loading configurations	To ensure that the CG changes in each configuration do not upset stability.
Emergency Protocol Tests	Ground tests which simulate a loss of connection or other failure	To ensure the aircraft performs the proper maneuvers in a given emergency situation.
Mock Ground Mission	A mock ground mission will be performed	To ensure all LRUs can be replaced within the given timeframe, with the aircraft still flight capable.

Table 4. Table of Test Planning for our Project

Our flight tests are scheduled to begin early in March. Pre-Flight checklists will be made to ensure all safety measures are in place, and the aircraft is ready for flight. Flight tests will be similar to competition flight missions so that we can estimate competition performance and explore our aircraft's flight characteristics such as speed, range, and endurance.

1.0 Executive Summary

The objective of the 2017-2018 AIAA Design/Build/Fly (DBF) competition is to design a dual purpose regional and business aircraft with line replaceable units (LRUs) for easy serviceability.

The University of Southern California AeroDesign Team chose a biplane configuration with a conventional tail in order to minimize wingspan. The biplane utilizes tip landing gear, which integrates into the end plates on the wings. The team designed a sixteen-passenger plane that can carry two eight-ounce cargo blocks for M_3. The seats in the passenger compartment are adjustable to accommodate each passenger size. Additionally, the plane's components are serviceable in order to complete the ground mission. Through a combination of in-lab testing and test flights, the team will validate the design and sizing of all aircraft components prior to the competition.

2.0 Management Summary

The 2017-2018 AeroDesign Team of USC consists of 30 students that participate on an extracurricular basis. One member of the team is a graduate student, five are seniors, and the remainder is underclassmen. The team is entirely student-led but receives guidance and suggestions 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, ensures adherence to the master schedule and works with the Operations Manager to obtain funding and manage team logistics.

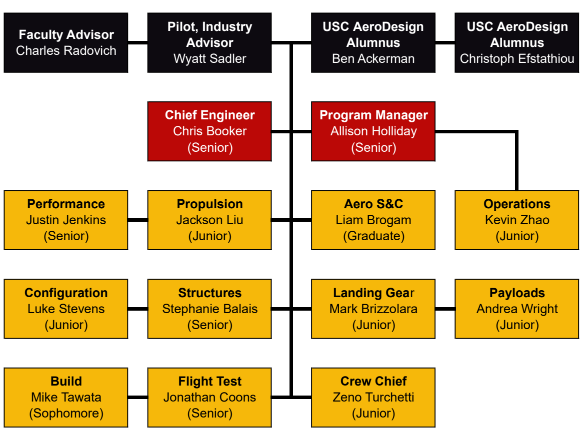


Figure 1: USC AeroDesign Team Organization

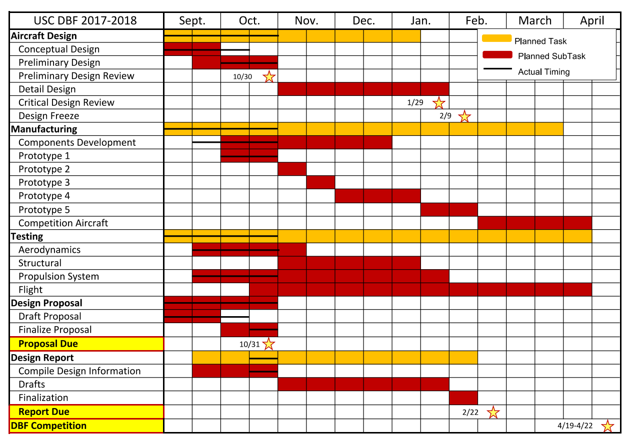


Figure 2: AeroDesign Team Milestone Chart

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 29-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 2017-2018 competition consists of $3,500 for lab tools, $17,500 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 Wichita through Southwest Airlines and will be staying in the Super 8 Wichita Airport. The team will travel around Wichita in vans rented through Budget Rent a Car. The expected travel expenses of $11,500 will be covered through university funding and team funds, allowing the team to bring all captains and primary contributors to competition.

3.0 Conceptual Design Approach

In 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 end product of the conceptual design phase is the preliminary design presented in Figure 7.

Mission Requirements > The 2017-2018 DBF competition consists of three flight missions and one ground mission. The plane for this year's contest is intended to simulate a dual purpose regional and business aircraft. The mission descriptions and scoring are shown below.

Table 1: Mission scoring and descriptions for DBF 2018

Mission	Successful Mission Score	Flight Description
Display Flight	$M_1 = 1.0$ (Successful flight)	3 laps, no payload
Ground Mission	No Score	Two stages of removing and replacing randomly chosen components
Short Haul Flight	$M_2 = 2 * \frac{(N_{PAX,M2}/T)_{USC}}{(N_{PAX,M2}/T)_{BEST}}$	3 laps, team-specific number of passengers
Long Haul Flight	$M_3 = 4 * \frac{(N_{LAPS} * N_{PAX,M3} * W_{CARGO})_{USC}}{(N_{LAPS} * N_{PAX,M3} * W_{CARGO})_{BEST}} + 2$	Team-specific laps, team-specific number of passengers and cargo weight

Scoring Summary > The overall scoring equation for DBF 2018 is shown in Equation 1.

$$SCORE = \frac{(ReportScore * FlightScore)}{RAC}$$

$$FlightScore = M_1 + M_2 + M_3$$

$$RAC = EW * WS$$

Equation 1: Scoring Equation for DBF 2018

The empty weight of the aircraft, EW is the maximum, post-flight weight of the aircraft with the payload removed. The wingspan, WS is the longest distance between wingtips measured perpendicular to the axis of the fuselage. Both of those parameters are driving factors in the rated aircraft cost, RAC.

Score Analysis > Initial score analysis, shown in Figure 3, indicated that the scoring equation was most sensitive to the empty weight of the aircraft, the wingspan of the aircraft, and number of passengers carried in M_2. By linking the increase in payload carried with increased wingspan and empty weight, it was determined that the optimum number of passengers to carry in M_2 would be sixteen. In order to minimize weight and drag, two eight ounce cargo blocks (2”x2”x5”) were chosen to carry along with eight passengers for M_3.

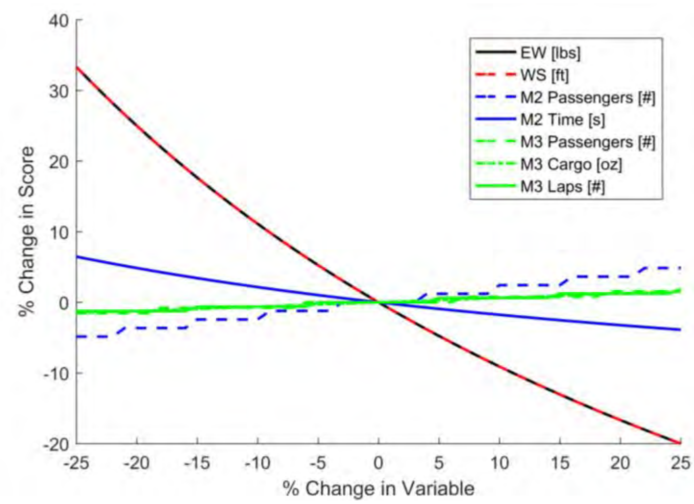


Figure 3: Preliminary Score Analysis

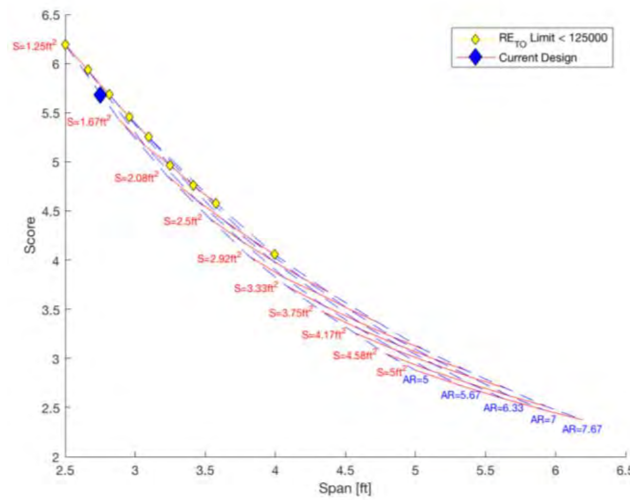


Figure 4: Total Score vs wing AR, S and b

Configuration Analysis > The team considered numerous configurations in the conceptual design phase. It was determined that a blended wing body or a biplane was the highest scoring configuration. Analysis was performed to analyze the tradeoff between wingspan and the empty weight for both configurations; it was determined that a biplane would have the highest scoring combination for the smaller wingspan and larger empty weight.

Preliminary Design > The team collaborated to design all aircraft components to meet the three design objectives: minimize wingspan, reduce empty weight, and maximize passengers carried for M_2.

Wing Geometry > Trades 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 takeoff field length (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. To avoid problems with stall at low Reynolds numbers, the team fixed the minimum chord length at 6.5 inches to remain about Re = 125,000. The tradeoff between wing geometry and score is shown in Figure 4. The preliminary configuration, shown as a blue diamond, has AR = 5 and S = 1.51 ft^2.

Aerodynamics > In order to meet the Takeoff Field Length (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 SD5060 airfoil was used due its high C_{Lmax} of 1.25 and low $C_{DCruise}$ of 0.00795.

Wings of varying gap distances were run in AVL with the same flight conditions and the lift coefficients were compared to that of a mono-wing of the same span and AR. The gap distance needed to achieve adequate lift for this wing size is 4 inches. This coincides with the minimum fuselage height of 4 inches in order to meet the spatial requirements for the passenger compartment with a cargo bay below it. End plates were added to the biplane design to improve the effective aspect ratio of the wing. Further parameters will be investigated such as decalage and taper in order to further improve the aerodynamics of the biplane configuration.

Propulsion > To meet a 150 TOFL, analysis determined that the static thrust required at takeoff was 1.6 lbs. For preliminary testing, a Hacker A20-12XL EVO (1039 KV) motor was used with a CAM 8x7 folding propeller and 10 x Elite 1500 mAh NiMh cells. This package meets the performance requirements for M_1 and M_2, but will require additional cells in order to sustain flight for the duration of the 10-minute window in M_3.

4.0 Manufacturing Plan

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 Configuration Lead designs the aircraft based on data from the Performance, Aerodynamics and Propulsion Leads. Completed design drawings are passed to the Structures, Build and Crew Chief Leads who select materials and lead the manufacturing effort.

The team has completed prototypes of preliminary design of subcomponents of the aircraft; the prototype for the passenger seat with restraint is shown in Figure 5 and the prototype of the servo LRU is shown in Figure 6. The passenger restraint consists of a foam seat with wire that can adjust to wrap around any size passenger. The servo LRU is a balsa wood box that holds the servo in place along a rib of the wing; however, the pins can easily be removed to replace the servo for the ground mission. The team is currently working on designing, building, and testing lightweight components for integration into the next iteration of the aircraft.

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 shear web, and SOLITE skin. Further structural analysis 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 the LRUs will occur concurrently with the development of the plane's landing gear, wing, tail, and fuselage. The initial schedule for aircraft and component production is shown in Figure 2.

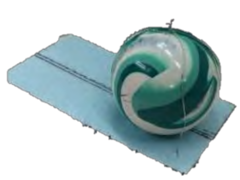
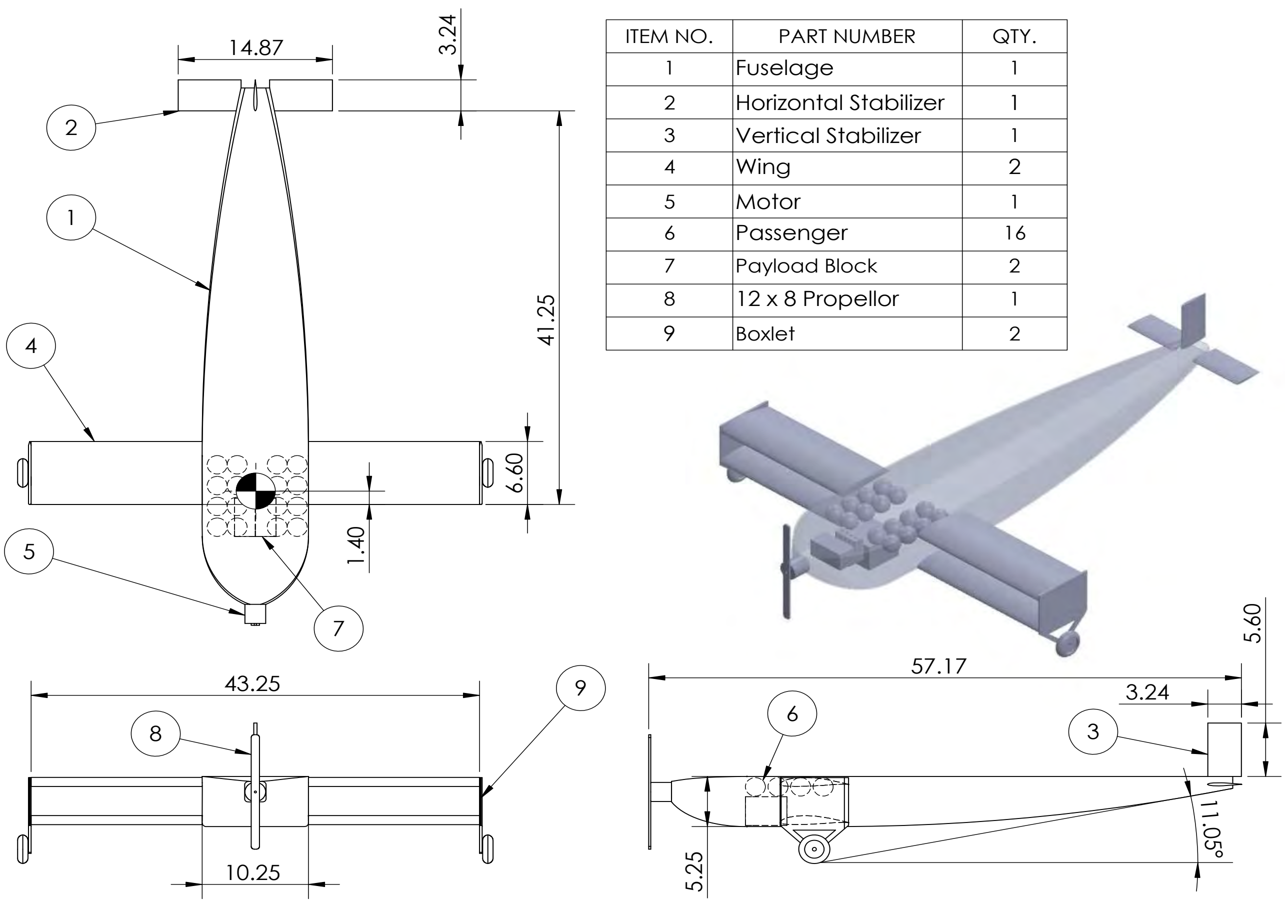


Figure 5: Passenger Seat and Restraint

Figure 6: Servo Line Replaceable Unit

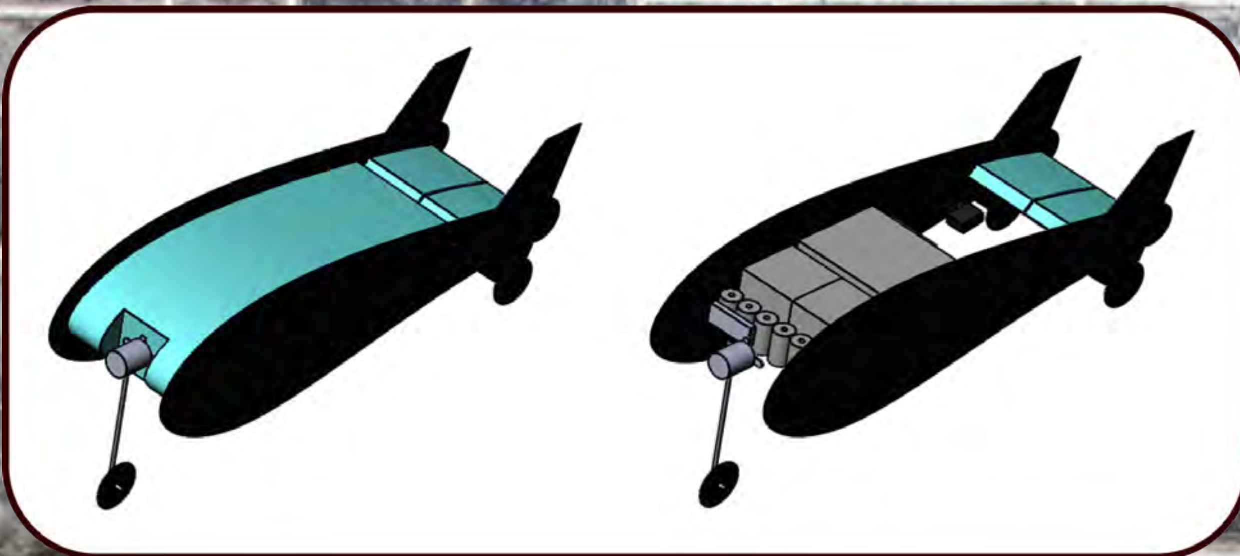
5.0 Test Planning

Prior to the 2018 Competition, all aircraft components and missions will be tested through a combination of test flights and in-lab testing. The first iteration of the full aircraft prototype will be used to validate the preliminary sizing and aerodynamic performance of the plane. Propulsion system performance is evaluated for static conditions in lab using a dynamometer. Data is collected at test flights using a logging ESC in order to evaluate dynamic performance of the batteries and motor. Test Flights are scheduled at the conclusion of the build cycles shown in Figure 2. Test flight objectives and test plans depend upon the lessons learned and overall performance throughout the year. Following the completion of all missions with the foam aircrafts as early prototypes, the team will move on to structural load testing of the individual components to ensure that the wing, tail, and fuselage can withstand in-flight and landing loads. Similarly, landing gear will be tested to withstand takeoff and landing loads. Additionally, individual testing will be done on the LRU components to ensure that replacements can be done in the allotted time.



ITEM NO.	PART NUMBER	QTY.
1	Fuselage	1
2	Horizontal Stabilizer	1
3	Vertical Stabilizer	1
4	Wing	2
5	Motor	1
6	Passenger	16
7	Payload Block	2
8	12 x 8 Propellor	1
9	Boxlet	2

Figure 7: Preliminary Design of the Aircraft – 3 View and Bill of Materials (all dimensions in inches)



Virginia Tech
Design Build Fly Proposal
2017-2018

Susan Bowen, Zoe Guernsey, Erik Higgins, John Kiene, Austin Kleinfelter, Atul Kumar, Sapna Rao, Brady Reisch, JP Stewart

Executive Summary:

The Virginia Tech team is pleased to propose an innovative aircraft that maximizes the passenger/payload carrying ability while minimizing the rated aircraft cost (RAC). The AIAA DBF Organizing Committee has determined the need for a mixed-use regional/business aircraft that can fulfill the role of passenger short haul and can quickly be reconfigured to provide long haul passenger and payload missions. The Virginia Tech team has studied the customer's needs and requirements through scoring analysis, trade studies, and preliminary design.

With span and weight as the primary scoring drivers, this single seat aircraft can carry 1 oz. of payload and complete at least three laps with a span of 4.5" and a maximum takeoff weight of 0.75 lbs. This configuration provides the customer with the highest scoring design.

Management Summary:

The multi-disciplinary team consists of students of all academic levels and experiences. The nine sub-team leads shown in Figure 1 manage their functional groups and are responsible for educating their underclassman teams to ensure future continuity. The Chief Engineer will ensure technical excellence and collaboration across the team. The Project Manager owns the project plan, budget, travel arrangements, and team outreach. The Aerodynamics team is responsible for sizing the planform, generating the outer mold line (OML), and performance analyses. The Stability and Control team determines control surface sizing, analyzes static/dynamic stability and control to help determine the OML. The Propulsion group determines the motor, battery and ESC sizing and conducts testing for performance and reliability. The Structures team owns the CAD model, designs the internal structure and conducts analysis and test on it's designs. Manufacturing is responsible for determining the manufacturing methods and the design and build of the necessary tooling. The Systems and Report lead will maintain the system and sub-system requirements and ensure compliance across teams. The Underclassman lead serves with the senior team and is co-leading Propulsion and Manufacturing.

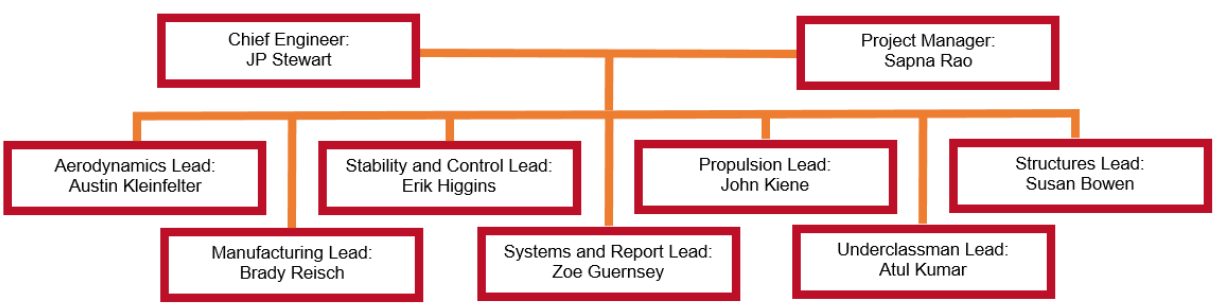


Figure 1. Team Organization Chart

The program's high-level Gantt chart is provided in Figure 2 and is used for communicating design phases and major milestones. This compliments the detailed internal program plan and 150+ line WBS that is used for tracking progress.

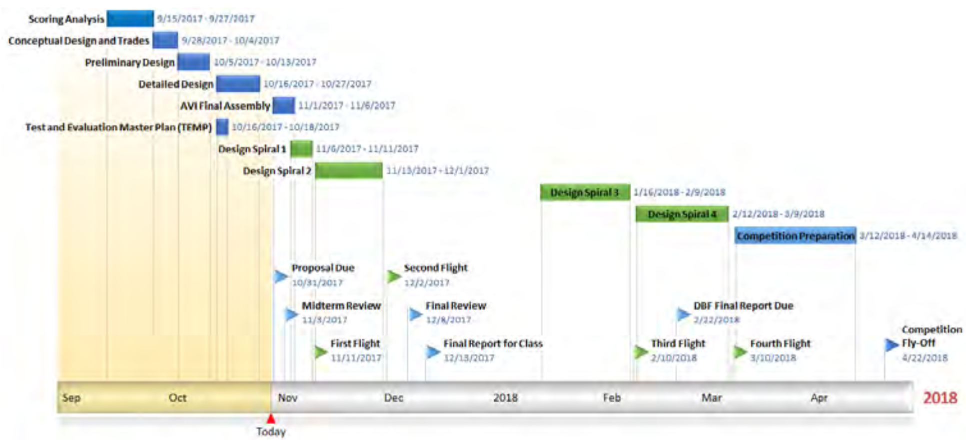


Figure 2. High-Level Gantt Chart

The team operates on a budget of approximately $20,000 which is allocated to the categories shown in Table 1. This funding is available thanks to industry donations and the Virginia Tech Kevin T. Crofton Department of Aerospace and Ocean Engineering.

Table 1. Team Budget

Category	Amount
Build materials	$7,000
Workspace improvements and tooling	$5,000
Outreach and recruiting	$1,000
Competition travel	$7,000

<u>Conceptual Design Approach</u>:

Design Build Fly's 2018 RFP calls for the design, build, and flight demonstration of a regional class passenger aircraft. This aircraft must be able to transport bouncy ball "passengers" and payload blocks that are sized by the team (L + W + H = 9"). This aircraft must be ready for rapid servicing and therefore must be equipped with field and depot replaceable LRUs which will be tested during the ground mission. Flight Mission One simulates an aircraft staging flight with no passengers or payload and a short three lap flight within five minutes. Flight Mission Two is a short haul flight (three laps within five minutes) with the maximum number of passengers and no payload. Flight Mission Three emulates a long-haul flight with the team's choice of passengers and payload. The team may complete as many laps as possible within a 10 minute window.

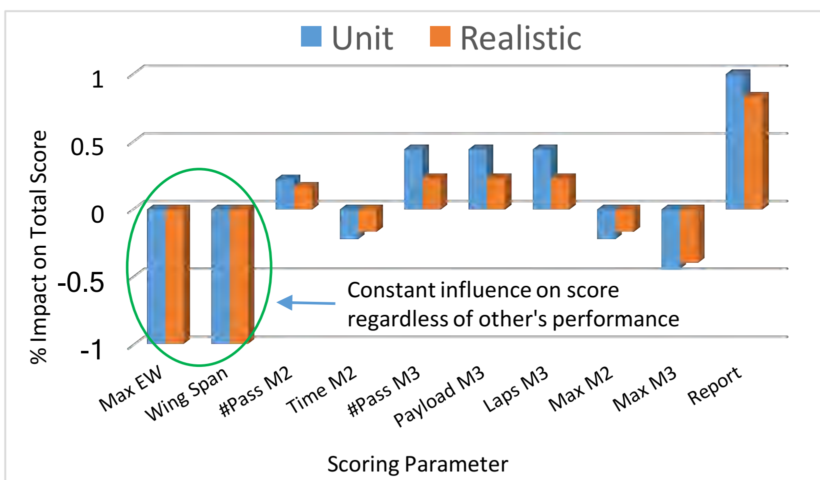


Figure 3. Influence Coefficient Comparison for Unit and Realistic Values

Scoring analysis was used to identify the primary design drivers. By taking the partial derivative of the scoring formula with respect to each variable, Figure 3 was generated. The unit analysis assumes all scoring formula inputs are one. Estimates of realistic maximum scores for other teams were generated for the number of laps, number of passengers, and payload weights. These estimated values were then used to generate new ("Realistic") influence coefficients. This shows that the influence of empty weight and wing span are independent of the performance of other teams. Assuming that at least one other team chooses to maximize laps, passengers, or payload, the Virginia Tech team can exercise the most control over its score by minimizing span and weight. To validate this, historical DBF data was used with a non-linear excel optimization tool to parametrically "design" and score various configurations. This allowed the interactions between each scoring variable to be considered. For example, it showed that an aggressively designed aircraft with 16 passengers, 20 oz payload, 30" span, and 1.67 lb empty weight would have an estimated score of **0.12** while a small aircraft with one passenger, 1 oz payload, 4.5" span, and 0.75 lbs empty weight would have a score of **0.90**. Because of the >7x increase in score, the team decided to prioritize span and weight.

A series of design concepts were generated in NASA's OpenVSP and the top four were sized and down-selected using the selection matrix given in Table 2. The ranking was qualitative while the weights were determined from the influence coefficients shown in Figure 3. The lowest total score number determined the best design and the Wing-A-Lage was chosen to proceed to a more refined sizing.

Table 2. Selection Matrix

Design Number	1	2	3	4	
Design Concept	Blended Wing-Body	Bi-Plane	Oblique Wing	Wing-A-Lage	Weighting
Empty Weight	3	1	4	2	35%
Wingspan	4	3	1	1	35%
Passenger Capacity Score	2	3	1	3	10%
Payload Capcity Score	2	4	1	3	10%
Manufacturability	2	1	1	1	10%
Total Score	76.25	55	51.25	43.75	

The Wing-A-Lage (shown on the title page and in Figure 4) was designed around the minimum possible span that a one pasenger (and aisle) aircraft with 1 oz. payload could feasibly have. To size the aircraft, an internal layout was assumed and the minimum possible span was found to be 4.5". The 15" chord of the wing was sized by estimating a 20% thick airfoil and ensuring 0.25" of clear space on all sides of the passenger, aisle, and payload is maintained for structure. A weight build up of the various subsystems estimated a takeoff gross weight (including the maximum passenger weight and 1 oz of payload) to be 0.7 lbs. Potential airfoils were tested using XFOIL and a 3D C_L correction was estimated based on the results of a low aspect ratio literature review. This resulted in a takeoff speed of approximately 45 mph.

Various trade studies were conducted to study the sensitivity of design parameters. Figure 5 demonstrates the primary trade studies between span, takeoff speed, takeoff distance, static thrust, and C_L. These trade studies show the aircraft operating range is within the realm of reasonable values and meets the RFP performance requirements. Due to unaccounted for effects such

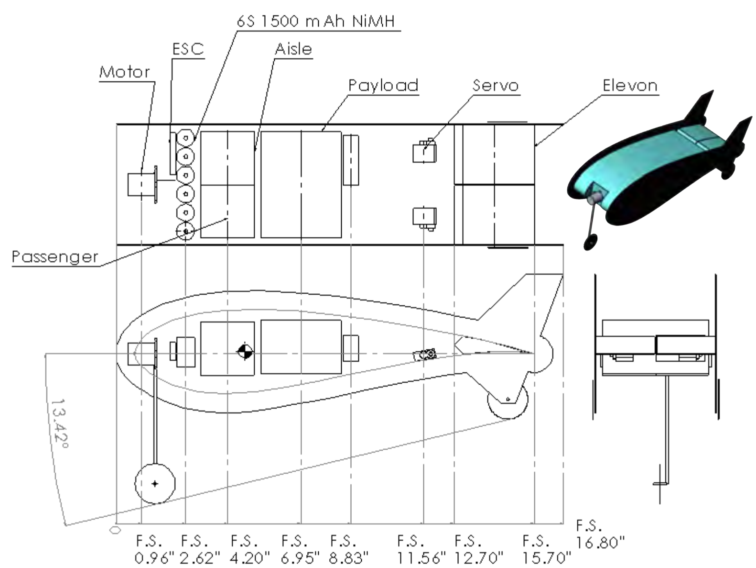


Figure 4. The Wing-A-Lage 3-View Drawing

as increased flow from the propeller, the inclusion of end plates, and uncertainties in analysis of low-aspect ratio aircraft; testing is necessary to validate these trade studies.

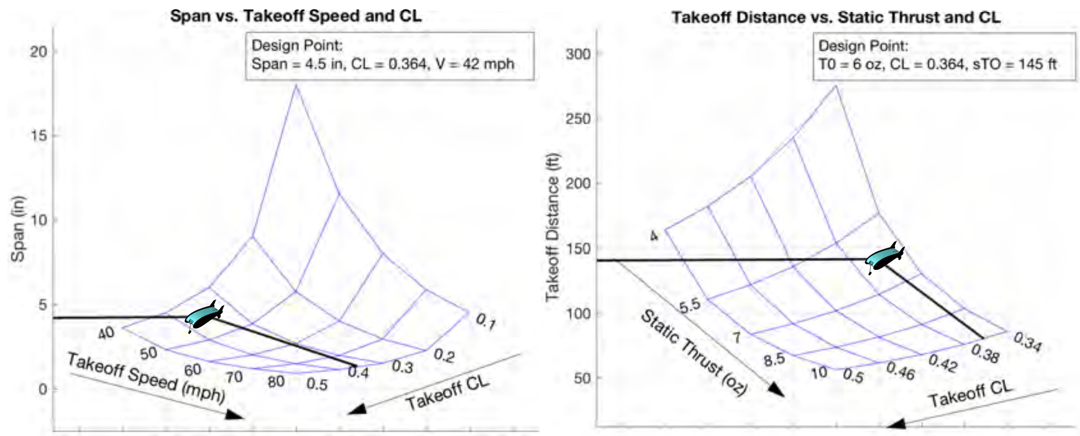


Figure 5. Carpet Plots of Key Design Drivers

Manufacturing Plan:

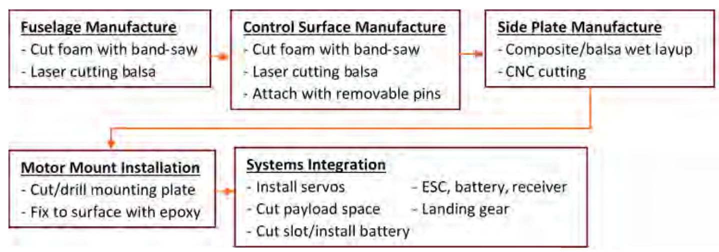


Figure 6. Prototype Manufacturing Flow

The manufacturing build process for the prototype aircraft is shown in Figure 6. The build process is designed to be as simple as possible and allow for quick prototyping and design iteration. As the design matures, further manufacturing trades will be tested and other options considered. The team has considerable experience with critical processes such as foam prototyping, balsa built-up construction, and composites. Therefore, the final selection criteria of the production aircraft build process will be weight. Due to the modular nature of the LRU's, the team is relying on several critical technologies such as pinned hinges, a removable gear, and accessable components to allow for quick LRU replacement.

Test Planning:

RISK MATRIX			SEVERITY			
			CATASTROPHIC	CRITICAL	MARGINAL	NEGLIGIBLE
			1	2	3	4
FREQUENCY	FREQUENT	A	0	0	0	0
	PROBABLE	B	0	1	0	0
	OCCASIONAL	C	3	7	1	0
	REMOTE	D	1	5	6	0
	IMPROBABLE	E	0	0	0	0

Figure 7. Preliminary Design FMECA

A preliminary FMECA (Figure 7) has been conducted to identify prediction uncertainties in addition to hardware failure modes. This FMECA identifies the number of risks for each category and is used to guide the ground and flight tests plans. The primary ground test priorities (and high-risk FMECA items) are currently validation of performance and stability estimates using the Virginia Tech Open-Jet wind tunnel, component testing, and manufacturing prototyping. A flight test of the first design iteration will be conducted by November 11, 2017 to identify "unknown unknowns" and validate ground handing assumptions. The lessons of these ground and flight tests will be fed into later design spirals and several flight prototypes will be built to refine the design. In the new year, the testing focus will shift from performance validation to mission readiness and the aircraft will begin flying simulated competitions to evaluate reliability.

Washington University in St. Louis

1 Brookings Drive
St. Louis, MO 63130

Design Proposal

For the 2017-2018 **AIAA Design Build Fly Competition**
On behalf of **Washington University Design/Build/Fly**
31 October 2017

1. Executive Summary

1.1. Objective Statement

Washington University Design/Build/Fly (WUDBF) will design and manufacture the *Spruce Zeus*, an aircraft to compete in the 2018 AIAA Design Build Fly (DBF) competition. At competition, WUDBF aims to place within the top ten teams. WUDBF seeks to expand opportunities for experiential learning in engineering at Washington University while continuing to foster connections between team members and the professional engineering community.

1.2. Approach

As an organization, WUDBF will succeed by properly managing its resources of time, money, and workforce. WUDBF has included redundant safety factors in its schedule by allocating time for flight testing of the competition vehicle, budget -- with minimum funding of $8,000; and roster -- by assigning multiple students to a task, which ensures a timely completion.

From a design perspective, WUDBF will analyze the mission parameters and scoring criteria through a tradespace study (Figure 3) to discover which configurations score highest. In this year's competition, score is determined primarily by the number of passengers and weight of payload carried; this score is then divided by rated aircraft cost (RAC), which is wingspan multiplied by empty weight. Preliminary design analysis indicates that a small, light aircraft with a low RAC carrying the least amount of passengers and payload possible will yield the highest score.

2. Management Summary

2.1. Organization

To facilitate efficient communication and work, WUDBF is organized into an Executive Board and three design divisions, listed as follows:

2.1.1. Executive Board

The executive board consists of the faculty advisor, the graduate student advisor, the president, the vice president, and the treasurer. The executive board is responsible for administrative tasks, resource allocation, and public relations.

Skills required for the executive board are management focused: engineering leadership, presentation skills, and organization.

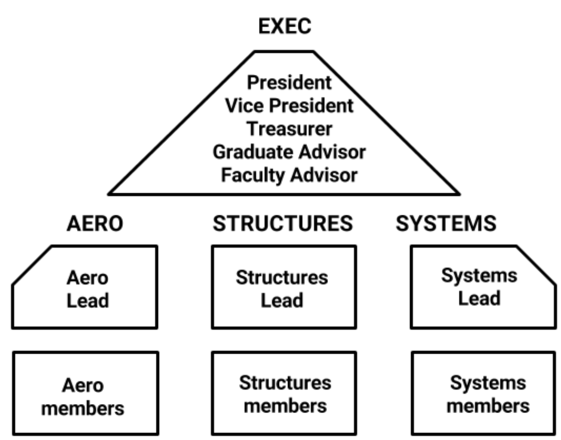


Figure 1. WUDBF Organization

2.1.2. Aero Division

Aero is responsible for the design of the outer shape of the aircraft in accordance with aerodynamic principles. It is also responsible for preliminary computational fluid dynamics (CFD), performance prediction, and stability analysis of the selected design. During manufacturing, the Aero division manages construction of the airplane's skin and control surfaces.

Required skills: CFD, aircraft dynamics, and systems engineering.

2.1.3. Structures Division

Structures is responsible for airframe design and mechanical interfaces for actuated components. Additionally, the division is responsible for structural analysis, computer-aided design (CAD) modeling, and mass properties management. During manufacturing, the Structures division coordinates and manages construction of the airframe.

Required skills: CAD, structural finite element analysis, mass properties, and airframe manufacturing.

2.1.4. Systems Division

Systems is responsible for the design and implementation of electrical components of the aircraft, including the propulsion system (propeller, motor, electronic speed controller, flight battery), communications (transmitter/receiver, telemetry, auxiliary batteries) and control systems (control surface servos, flight controller, inertial measurement unit). During manufacturing, Systems ensures all electronic components are properly integrated into the airframe.

Required skills: signal and aircraft control theory, circuit design, and microprocessor integration.

2.2. Schedule

The following Gantt charts show WUDBF's schedule from the release of this year's rules to the competition in April. Note that each task extends until the end of the year, but the "Actual" timelines terminate at the proposal submission date.

Table 1: Aircraft Design/Manufacturing/Testing Timeline

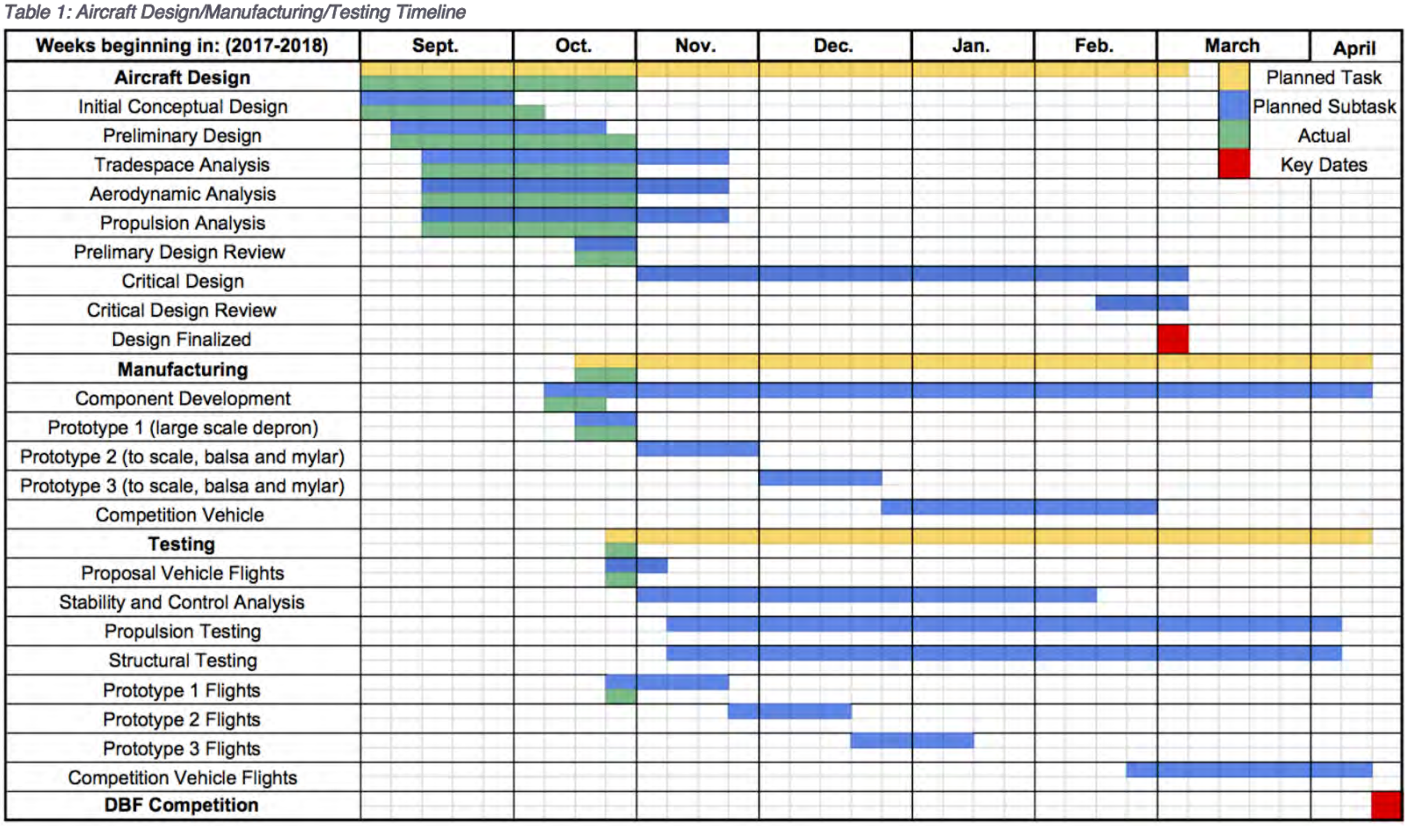
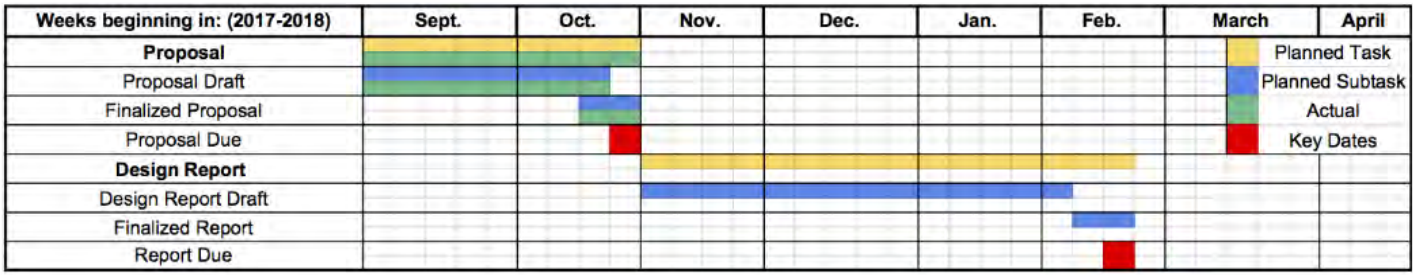


Table 2: Documentation Timeline



2.3. Budget

Funding for the Fall 2017 semester comes from two primary sources: Washington University Student Union (SU) and the Engineering Project Review Board (EPRB), a School of Engineering and Applied Science (SEAS) fund. For Fall 2017, WUDBF received $500 from SU and $2,000 from EPRB. Additionally, SolidWorks is now a team sponsor, providing 30 copies of their SolidWorks software for the team.

Spring 2018 funding will come from the same sources. WUDBF expects to get $6,000 of SU funding and $2,000 from EPRB. Travel funding will come primarily from SU, but also from EPRB and other SEAS sources.

Table 3: Costs Breakdown:

Description	**Cost**
Construction materials	$1,200
Electronics	$1,200
Travel: Cars and Gas	$2,070
Travel: Lodging	$2,600
Travel: Food	$1,830
Total:	$8,900

3. Conceptual Design Approach

3.1. Mission Requirements

This year's DBF challenge is to build a "regional and business aircraft" that can carry both passengers and payload in two separate compartments. There are four separate missions in this competition. Missions 1 through 3 test the aircraft's capabilities in flight. Points are allocated from Mission 1 by successful completion of the course, Mission 2 by the number of passengers carried with respect to completion time, and Mission 3 by the product of laps completed, number of passengers, and payload weight carried. The fourth mission, the Ground Mission, is to replace two Line Replacement Units (LRUs) in a single 8-minute time window; LRUs to be replaced are determined by dice rolls. Successful completions of both Mission 1 and the Ground Mission are required to attempt Missions 2 and 3.

3.2. Preliminary Design and Analysis

WUDBF has designed its competition vehicle, the *Spruce Zeus,* to maximize score by minimizing RAC while remaining versatile in adverse weather.

Performance, or total score, is determined by the following equation:

$$SCORE = \frac{Written\ Report\ Score \cdot (M_1 + M_2 + M_3)}{RAC}$$

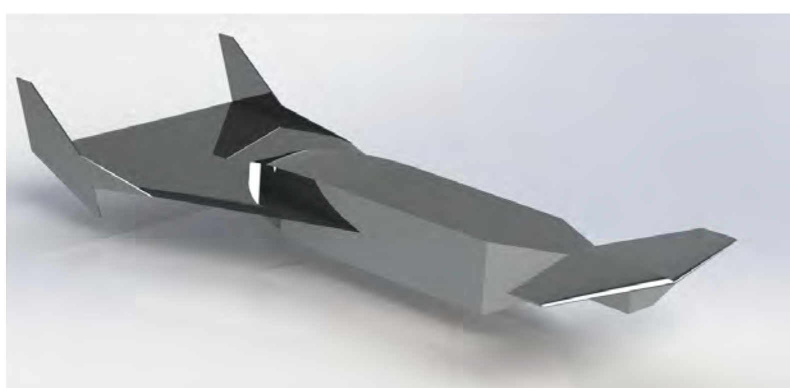


Figure 2: Initial Design of the Spruce Zeus

RAC is determined as $RAC = EW_{Max} \cdot WS$, where EW_{Max} is maximum empty weight of the aircraft (lbs) and WS is wingspan (in). Each mission is scored as follows:

Mission 1: $M_1 = 1$ for completion.

Mission 2: $M_2 = 2\frac{(Passengers/Time)_N}{(Passengers/Time)_{Max}}$

Mission 3: $M_3 = 4\frac{(Passengers \cdot Payload(oz) \cdot Laps)_N}{(Passengers \cdot Payload(oz) \cdot Laps)_{Max}}$

Preliminary sizing analysis has determined that smaller aircraft will fare best in this competition because minimizing RAC will yield the highest score, even at the cost of carrying fewer passengers and payload, as seen below (Figure 3).

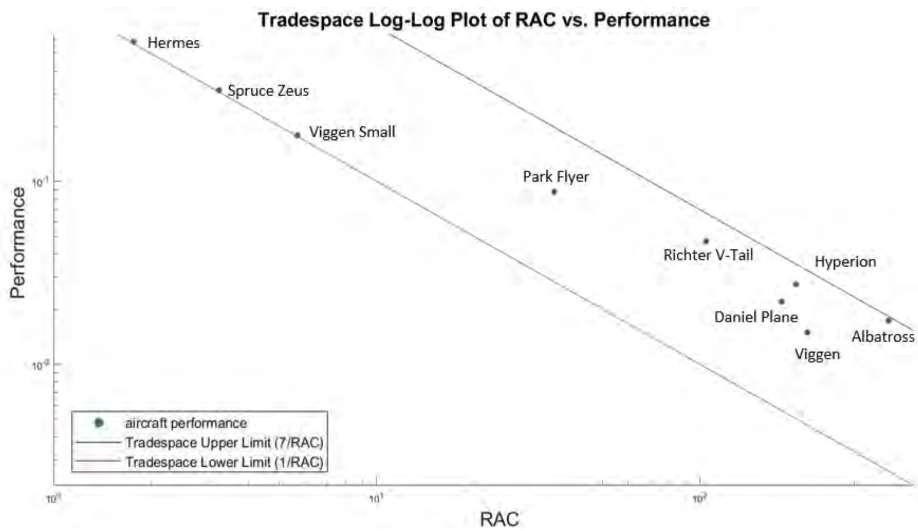


Figure 3: Preliminary Tradespace Analysis, Including Upper and Lower Bounds for Performance vs. RAC

Based on the scoring guidelines for this year, the maximum mission score for all three flight missions is 7, and the minimum is 1. Because total score is mission score divided by RAC, the lines in Figure 3 represent the upper and lower bounds of performance. In short, this study indicates that RAC matters more in terms of total score than aircraft capability.

Therefore, the *Spruce Zeus* is designed to carry only a single passenger and one payload block to allow for a projected empty weight of .44 pounds (using balsa and mylar construction) and a wingspan of eight inches. This analysis is further discussed in the sensitivity study below.

3.3. Sensitivity Study

To determine the partial derivatives of total score with respect to configuration wingspan, propeller pitch, and total pack voltage, a sensitivity study was conducted. The results are displayed below (Table 4):

Table 4: Sensitivity Study, Including Partial Derivatives of Total Score with Respect to Different Parameters

Sensitivity Study Results		
Partial with Respect to Wingspan	Partial with Respect to Propeller Pitch	Partial with Respect to Pack Voltage
-0.0016 (score/mm)	0.00055 (score/in)	-0.0461 (score/V)

These results indicate that an increased propeller pitch or a decreased battery pack voltage slightly increases the final score. However, an increase in propeller pitch provides a negligible increase in score. Also, a decrease in pack voltage significantly decreases the weight of the plane, reducing its resistance to high winds. A decrease in wingspan increases the performance without significantly reducing the vehicle's capabilities. Therefore other aerodynamic configurations with spans less than that of the *Spruce Zeus*, such as the *Hermes*, are being considered, as shown in Figure 3.

4. Manufacturing Plan

4.1 Preliminary Manufacturing Flow

Construction will be led by the Structures division. The possible configurations being considered are "small" and "compact", driving a mylar covered-balsa wood design, with sparse use of basswood to handle compressive loads. Because the design is small, there is no need to construct smaller prototypes before a full scale model. Instead, for ease of construction and better handling, the prototypes will be larger than the actual design. To complete construction, balsa wood will be cut to size, glued with cyanoacrylate (superglue), and set for six hours.

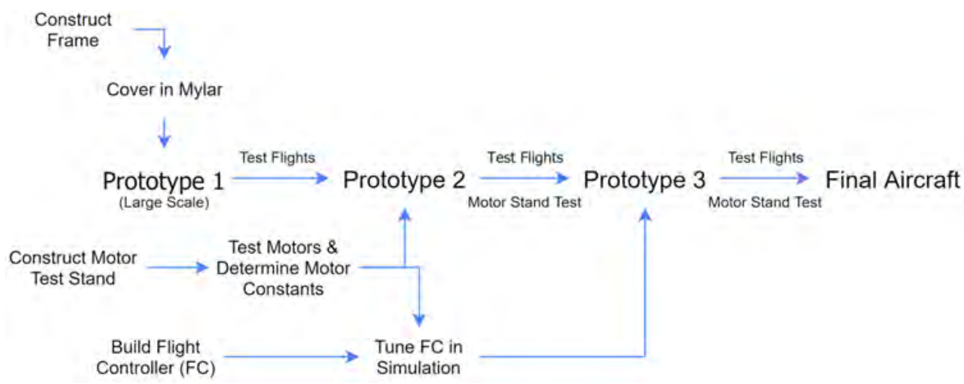


Figure 4: Manufacturing Flowchart

4.2 Critical Processes/Technologies

The most critical technology to be developed in this competition is an electronic flight controller. Small aircraft such as the the *Spruce Zeus* often suffer from poor handling qualities in even moderate wind, a common problem in this year's competition city of Wichita, so in response, the Systems team plans to incorporate a flight controller to improve these qualities. With a Proportional-Integral-Derivative controller that accepts inertial measurement unit input, tuned via MATLAB simulation, WUDBF will ensure that the airplane remains controllable and stable despite wind.

To further reduce risk during development, the aircraft is based on mature model building techniques and materials, using mostly balsa wood, cyanoacrylate, and mylar.

5. Test Planning

5.1 Component and Ground Test Plan

Ground testing will examine four components. The power system will be tested for performance, the airframe for structural integrity, the control surface servos for maximum torque, and the flight batteries for capacity. A custom-built motor test stand allows the Systems division to plot thrust curves for various motors and propellers. Furthermore, the electronics will be tested for transmission range and flight controller stability so that the plane acts predictably in wind and can fly the full course without loss of power or loss of radio link.

5.2 Flight Test Plan

Flight testing involves a series of test flights, altering parameters within each subsequent flight to cover various conditions. The first flights will carry no passengers or payload, but later flights will. Prototypes will fly with and without wind and use varying battery capacities to optimize performance. Because the *Spruce Zeus* is small, early models are larger in scale and successive models will decrease in scale until the final prototypes are of proper size.