I. Executive Summary

Our goal is to create a UAV that can transport, deploy, operate, and recover a towed sensor. We are accomplishing this by dividing the design, manufacturing, and reporting of work into various sub-teams, as discussed in Section II. To ensure that we maximize the points received during flight and ground operations, we performed a design parameter sensitivity analysis which lead us to prioritize a large sensor weight and quick ground operations. The design choices shown in Section III reflect these priorities.

Our UAV features a single wing with two booms and two vertical stabilizers. These design choices enable the stable deployment of the payload without risking damage to the airframe. We have investigated several different designs for the towed sensor, including wind tunnel testing to test for aerodynamic stability.

We will also be manufacturing multiple, full-scale prototypes, which will culminate in a stable and sturdy final airframe. Additionally, we will test our propulsion system design using a static thrust stand, validating that our system provides the necessary range and endurance. Furthermore, we will simulate the ground mission to ensure success at the competition.

II. Management Summary

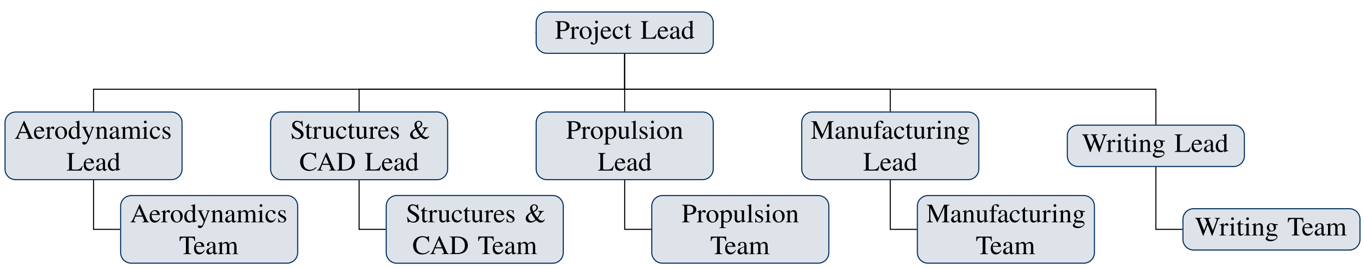


Figure 1 The BYU 2021 Design, Build, Fly team organization.

Table 1 Sub-Team Descriptions

Sub-Team	Role	Required Skills
Aerodynamics	Calculate performance metrics, stability and important aerodynamic values	MATLAB, XFLR5, familiarity with aerodynamic principles
Structures and CAD	Create 3D models and design the interior supports and structure	CAD software, introductory structural knowledge
Propulsion and Electronics	Design the electronic systems required to power and sustain the airplane in flight	Knowledge of propulsion and electronic systems including propellers, motors, speed controllers, transmitters, servos, etc.
Manufacturing	Construct and test prototypes. Lead in final construction and assembly of the flight model	Laser cutting, 3D printing, work with different materials and adhesives
Writing	Lead the writing of the proposal and final report	Technical writing, Microsoft Office, LaTeX

This year's BYU Aeronautics Club *Design, Build, Fly* team is designed to focus individual skill sets on relevant tasks. The nine team members are divided into five sub-teams, with each member expected to work actively on at least two sub-teams. These sub-teams, shown in Figure 1, enable the focusing of skills into accomplishing important work efficiently. Each sub-team is led by a team leader, selected based on their experience in each particular focus area.

The entire team meets weekly to discuss progress on individual sub-teams and the project as a whole. During these meetings assignments are made to the sub-teams, and each sub-team is then responsible to carry out their tasks and to coordinate with other sub-teams as necessary. The weekly meetings ensure that the project is progressing and provides an opportunity for teams to ask for input from other team members. If design conflicts arise between two aspects of the project developed by different sub-teams, then the ultimate decision is made by the sub-team leaders in conjunction with the project lead.

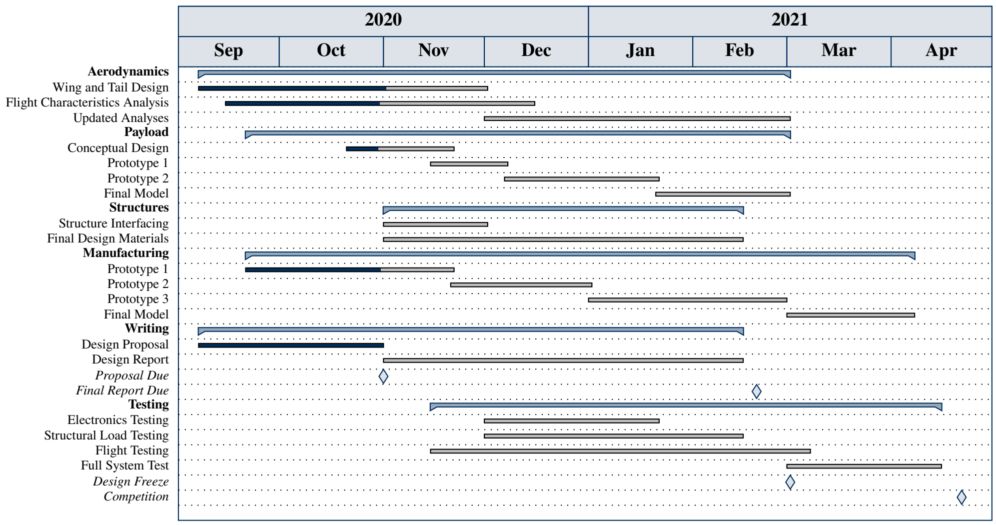


Figure 2 This milestone chart shows our plan for major elements of our design process.

A. Budget

Our prospected project budget is shown in Table 2. Included in our estimates are materials not only for the final aircraft, but also prototyping materials.

Table 2 Project Budget

Category	Items	Cost ($)
Propulsion	Brushless Motors (x2) | Propellers (x5) | ESCs (x2)	320
Power	6S Lipo Batteries (x2)	100
Structures	Balsa Wood | Monokote | ABS Filament (1kg) | Foam	150
Composites	Carbon Fiber Spars (x4) | Fiber Glass | Epoxy	160
Electronics	Servos (x10) | Receiver	110
Travel	Vehicle Rental | Gas (6 Members)	450
Lodging	Airbnb (6 Members)	900
Total		**2190**

III. Conceptual Design Approach

A. Mission Requirements

The aircraft must complete a ground mission and three flight missions as follows:

Ground Mission: The assembly crew team member must demonstrate payload accessibility, sensor resilience, and the sensor deployment/recovery mechanism functionality. The score is based on the time required to complete the ground mission.

Flight Mission 1: Staging flight: the aircraft must complete 3 laps of the competition course within a 5-minute window. One point is awarded for a successful flight.

Flight Mission 2: Delivery Flight: The aircraft will carry its maximum payload (sensor in shipping container, shipping container simulators, and deployment/recovery mechanism). The score is a function of the number of shipping containers carried, divided by the time required to fly 3 laps. An additional point is awarded for completing the mission.

Flight Mission 3: Sensor Flight: The aircraft will carry the sensor and the deployment/recovery mechanism. The aircraft will deploy the sensor, complete as many laps as possible in a 10-minute window, then recover the sensor and complete a successful landing. The mission score is the product of the number of laps flown, the sensor length, and the sensor weight. An additional two points are awarded for completing the mission.

B. Sensitivity Studies

We analyzed the sensitivity of the total mission score to design parameters. To simplify the analysis, we considered the scoring factors of Time from Mission 2 and Number of Laps from Mission 3 into a single design outcome: Speed. We discussed the collateral effects of the remaining scoring factors on the others, and decided to conduct our sensitivity analysis as if they were independent factors.

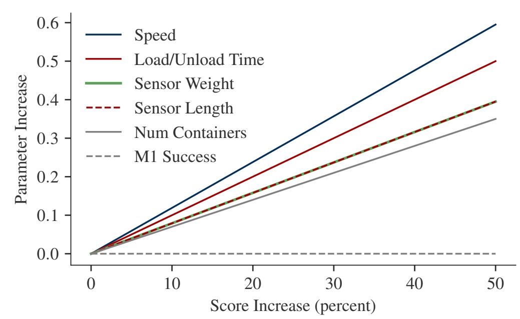
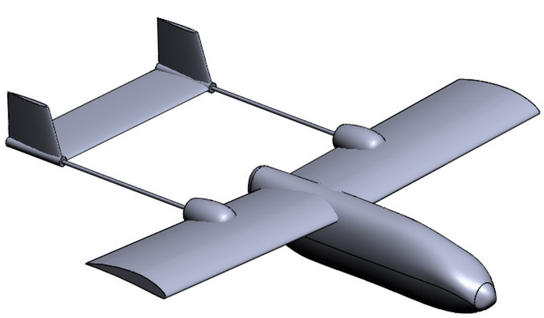


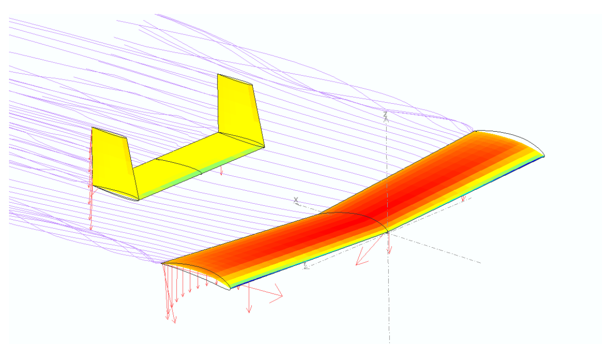
Figure 3 The sensitivity study of parameters.

According to the results of our sensitivity analysis, shown in Figure 3, the most important factors are the airplane speed and the time required to complete the Ground Mission. Therefore, our design will prioritize speed and easy access to the airplane cargo bay. Additionally, we decided to increase the sensor weight and decrease the number of packages to increase our score on the second mission. This also results in a faster load/unload time for the Ground Mission.

C. Preliminary Design



(a) A CAD model of our current design iteration.



(b) An XFLR5 analysis of our design showing the pressure distribution, streamlines, and downwash.

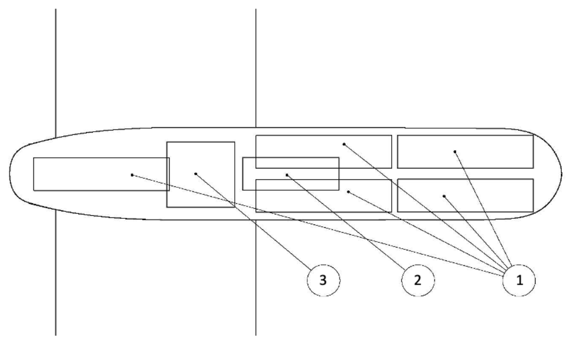
Figure 4 Images of our preliminary design.

Our design objectives are to maximize vehicle airspeed and minimize the cargo load/unload time. The following preliminary design is crafted to meet those objectives. As we continue testing, we will make further improvements to the design.

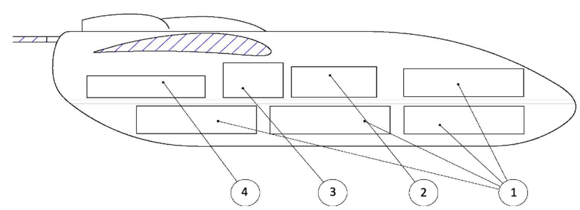
Configuration: We decided to use a single wing with a twin-boom tail. After researching the biplane configuration to maximize lift, we decided that a monoplane would be simpler and more stable, as well as enabling easier modular construction. The twin boom tail design allows the sensor to be deployed out the back of the fuselage without risk of damaging the tail and airframe.

Wing Geometry: Our wing was designed to achieve our goal of maximizing sensor weight, with the current iteration being designed to carry 10 lbs. Using XFLR5 to analyze the lift coefficient as a function of angle of attack, the aerodynamics sub-team selected a NACA 6412 airfoil and then selected a 12-inch chord for the entire wing. To further increase the lift in level flight, we mount the wing at an angle of attack of 3°. We improved stability by using a 3° dihedral and reduced the risk of tip stall by using a 5° root-tip washout. This configuration has a cruise speed of 48 mph with a 10 lb. takeoff weight.

Tail Design: The aerodynamics team determined that a "U" tail will maximize ground clearance and structural rigidity, especially with the twin boom design, while still enabling the airplane to be stable in the yaw axis. The tail uses NACA 0009 airfoils for both the horizontal and vertical stabilizers. Improvements will be made to the tail design as analyses and flight testing continue.



(a) Top-down view of fuselage.



(b) Side view of fuselage.

Figure 5 Interior views of the fuselage. Numbers correspond to 1) Shipping Containers, 2) Battery, 3) Winch Mechanism, and 4) Electronics.

Fuselage: The payload and propulsion teams determined that a streamlined box-style fuselage would be most effective for our priorities. We designed the fuselage with sufficient internal space for all necessary electronic components, mechanisms, and payload. Our fuselage design also facilitates balance adjustments to more easily achieve static stability.

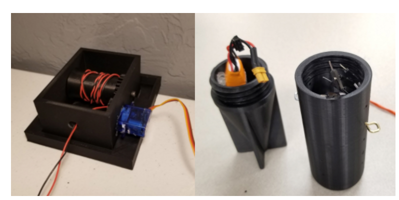


Figure 6 Current sensor rig: winch on left, towed sensor assembly on right

Payload: We have already investigated multiple potential designs for the towed sensor. We have used wind tunnel tests to explore various tow lines and tow locations along the sensor. In upcoming design iterations we will explore increasing the drag at the back of the sensor, similar to towed radar decoys used by military jets. An image of one of our tested designs is shown in Figure 6.

The deployment/recovery mechanism includes a 3D-printed winch connected to a metal geared servo motor. The winch is designed with a quick release base to facilitate quick installation and removal in order to decrease ground mission time. The control wires of the sensor pod will also serve as a tow line.

IV. Manufacturing Plan

The manufacturing team will construct CNC hotwire-cut foam-core wings, pine dowel tail booms, and a foam board fuselage. They will reinforce high stress areas with basswood and composite materials. We will use initial prototypes to acquire useful empirical data about the structure and flight performance of our design.

We plan to construct the wings and tail of the final model from balsa wood, the fuselage from balsa and composite materials, and the tail booms from carbon fiber dowels. We will fabricate various structural and functional parts from laser cut wood, and 3D printed plastics as well.

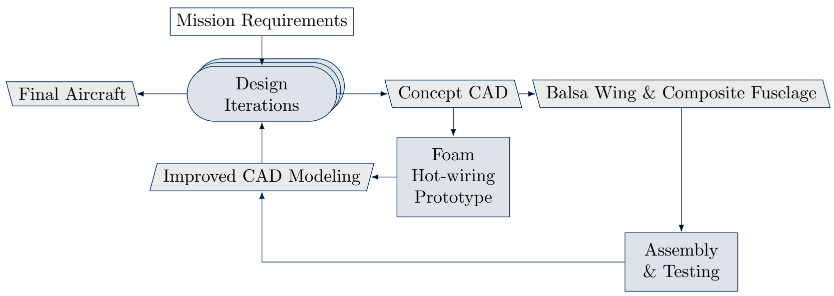


Figure 7 We show here a flowchart of our proposed manufacturing plan.

V. Testing Plan

A. Component and Ground Test Plan

Each team will regularly perform tests on their sub-systems during the design and revision process. The payload team will wind tunnel test the sensor pod to evaluate and improve aerodynamic stability at airspeeds within the flight envelope. The structures team will perform taxi and drop tests on the landing gear to ensure functionality. They will also conduct physical load tests on the main wing to ensure that the airframe can withstand flight forces. Using a static thrust stand, the propulsion team will evaluate the current draw and static thrust of several combinations of motors, batteries, and propellers to maximize flight speed and duration within our objective flight envelope. We will additionally perform simulations of the ground mission to evaluate the accessibility of the fuselage as well as practice and improve our performance for the competition.

B. Flight Test Plan

Foam prototype construction allows for high-speed prototyping to test and refine the airframe using real world flight tests over several design iterations. Prototypes of the full aircraft will be tested from late November through February (see Figure 2), with an example prototype shown in Figure 8. After we have validated our full design (to be completed by the end of February), we will perform flight tests with a balsa wood and composite final model. We will gather data via the pilot's perspective and from on-board sensors for all flight tests to evaluate and improve flight performance.

Figure 8 Current progress on Prototype 1. This prototype is full-scale and made primarily with foam.