Rutgers, The State University of New Jersey - New Brunswick

2020-2021 AIAA Design/Build/Fly Proposal

1.0 – Executive Summary

This proposal details RU Airborne's design, testing, and manufacturing plans for their entry into the 2020/2021 AIAA Design/Build/Fly competition.

The objective for this year's competition is to design an electric, remote-controlled aircraft that imitates a UAV with a sensor suite. The aircraft must carry at least one sensor within a shock-proof shipping container to simulate a transportation mission. The aircraft must also be capable of deploying a sensor from the aircraft and recovering it using a tow cable, simulating a surveillance mission. The sensor is required to be aerodynamically stable between deployment and recovery and have at least three external lights that flash in sequence.

The subsequent section outlines RU Airborne's organizational details. To maximize competition score, the team first conducted two detailed sensitivity analyses based on mission requirements to determine the most crucial mission parameters to design around. Through these analyses, it became apparent that the team's aircraft should accommodate a sensor of the maximum possible length. The results of this analysis were incorporated into the team's preliminary design for their aircraft. After considering several aircraft configurations, the team chose to design a single-motor, single-boom, T-tailed aircraft that will carry two 16 in. containers, one of which contains a sensor that will be deployed and recovered using a mechanism built around a servo. Finally, the team's plans for aircraft manufacturing and testing are outlined.

2.0 – Management Summary

2.1 – Organization Description

Subteam	*Roles*	*Required Skill Set*
Aerodynamics	• Determine optimal size and shape for aerodynamic surfaces based on stability analyses and performance calculations	• Knowledge of aerodynamic concepts • Use of aerodynamic simulation software
Manufacturing	• Machine parts and assemble aircraft • Prototype and test subsystems	• Knowledge of advanced manufacturing techniques and standard testing practices • Ability to read engineering drawings
Propulsion	• Select and test propulsion unit • Design necessary electrical systems	• Knowledge of mechatronics concepts • Experience with programming and soldering
Structures	• Design and model aircraft with 3D CAD software • Perform finite element analysis on parts	• Knowledge of design for manufacturability concepts • Experience with 3D CAD and finite element analysis software

Table 2.1: Subteam roles and required skill sets

RU Airborne is composed of approximately 25 undergraduate students who participate extracurricularly. Students range from freshman to seniors, with many upperclassmen having participated in several years worth of DBF competitions, ensuring continuous application of previous experience. The team is entirely student-led but occasionally consults their faculty advisor and team alumni during design reviews. The faculty advisor has the additional responsibilities of monitoring the team's progress and handling minor administrative tasks.

Day-to-day activities of the team are managed by the team lead, who is elected by the team members. The team lead manages the team's budget, finalizes all major engineering decisions, and coordinates the efforts of each subteam to ensure deadlines are met. RU Airborne is made up of four subteams, each of which are managed by a subteam lead. The role of each subteam and the skill set required by each subteam's members can be found in Table 2.1. In addition to regular design meetings, weekly meetings are held to provide a platform for all members to voice concerns, provide progress updates, and discuss major design decisions.

2.2 – Organization Chart

The hierarchical nature of RU Airborne is depicted in Figure 2.2. While each subteam is ultimately responsible for its area of expertise, members from different subteams are encouraged to work together to brainstorm ideas, critique current designs, and provide assistance when appropriate. The pilot is typically a member of one of the subteams that is experienced in flying RC planes.

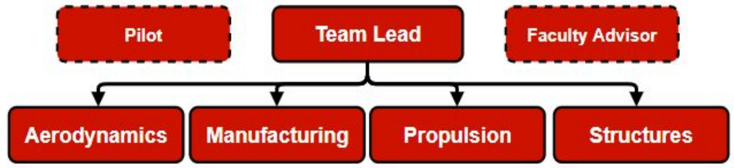


Figure 2.2: Organization chart

2.3 – Schedule

The team has created a Gantt chart, shown in Figure 2.3, to ensure that all major design milestones are met on time.

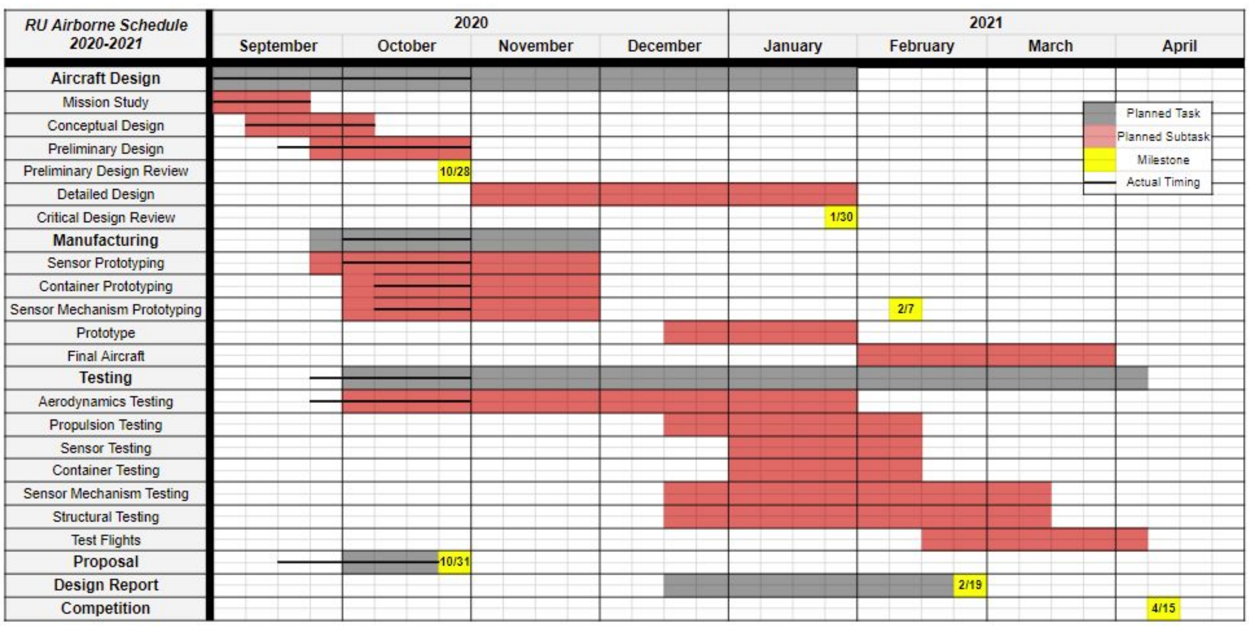


Figure 2.3: Schedule

2.4 – Budget

Figure 2.4 provides a summary of the projected expenses related to the construction of the team's aircraft, shipping of the aircraft, and transportation of team members to the competition site. The transportation portion of the budget is based on the team's prior experience. The majority of the team's funding is provided by the Rutgers Engineering Governing Council on a semesterly basis, while corporate sponsorships and membership dues cover the remaining budget deficit. The team will be flying to Tucson and renting a car on-site. The team's aircraft will be shipped in a crate to Tucson prior to the competition.

	Quantity	Item	Total Cost
Propulsion	2	Motors	$300.00
	2	ESCs	$200.00
	-	Batteries	$150.00
	4	Propellers	$60.00
	1	Transmitter/Receiver	$150.00
	1	Sensor Light System	$60.00
	20	Servo Motors	$60.00
	-	Wiring/Connectors	$20.00
Structures	-	Carbon Fiber/Epoxy	$400.00
	-	Balsa Wood/Monokote	$100.00
	-	Foam	$20.00
	1	Landing Gear	$30.00
	-	Push Rods	$10.00
Travel	-	Lodging (for six)	$1,100.00
	1	Vehicle Rental	$700.00
	6	Plane Tickets	$2,000.00
	-	Aircraft Shipment	$400.00
Total Cost			$5,760.00

Figure 2.4: Budget

3.0 – Conceptual Design Approach

3.1 – Mission Requirements

Task	*Mission Requirements*	*Subsystem Requirements*
Ground Mission	• Protect sensor (contained within shipping container) from repeated 10 in. drops • Load/unload sensors and shipping containers • Install the sensor and the deployment/recovery mechanism • Demonstrate deployment/recovery mechanism	• Shipping container must provide cushioning or shock absorption from all angles • Fuselage must allow for easy securing and removal of sensor containers • Fuselage must allow for easy securing of deployment/recovery mechanism
Mission 1	• Unladen aircraft must complete 3 laps in 5 minutes and successfully land	• Propulsion unit and main wing must be adequately sized for 100-foot takeoff
Mission 2	• Fully loaded aircraft must complete 3 laps in 5 minutes and successfully land	• Fuselage volume must be maximized • Propulsion unit must create high thrust-to-weight ratio for maximum velocity
Mission 3	• Aircraft loaded with sensor and deployment/recovery mechanism has 10 minutes to fly as many laps as possible • Sensor must be remotely deployed 10 times its length from back of aircraft and remotely recovered	• Sensor must be aerodynamically stable • Rear of fuselage must allow for easy sensor egress and ingress • Main wing and tail must account for moment caused by drag force on deployed sensor • Battery must have high capacity to maximize flight time

Table 3.1: Mission requirements and subsystem requirements

This year's competition involves designing an RC aircraft that mirrors a UAV with a sensor suite and has the ability to complete four missions. Table 3.1 outlines the requirements for each mission. The table also contains each requirements' impact on the various subsystems of the aircraft.

3.2 – Sensitivity Analysis

The team took two different approaches to determine the design parameters that have the most significant effect on the total mission score. Figure 3.2.1 shows the first approach, whereby the total mission score was calculated as a function of the sensor length and the number of containers, which are related to the other scoring parameters. The sensitivity analysis revealed that sensor length should be maximized instead of increasing container capacity. To confirm these results, the team conducted a second analysis (see Figure 3.2.2). This analysis sought to plot the percent change in the total mission score as a function of the percent change in each scoring parameter. The results clearly show that maximizing sensor length should be the priority for the team's aircraft, as increasing this parameter yields the greatest total mission score increase.

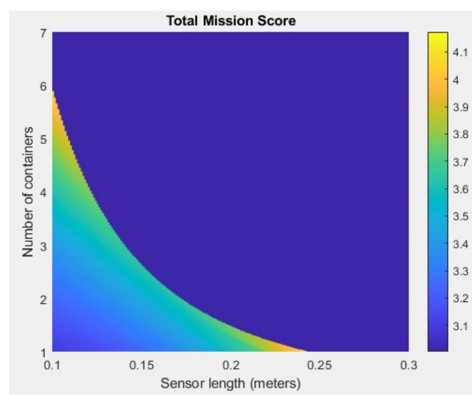


Figure 3.2.1 Initial sensitivity study

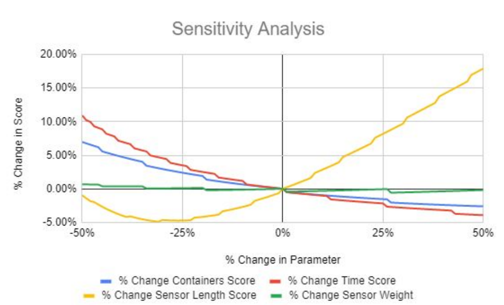


Figure 3.2.2 Subsequent sensitivity study

3.3 – Preliminary Design and Initial Sizing

Figure 3.3.1 depicts the current conceptual model for the team's aircraft based on the sensitivity study results. The plane will have a total length of 5.33 ft. and a wingspan of 4.90 ft. The fuselage will be approximately 10 in. wide by 8.50 in. tall and 63 in. long. It is designed to store two shipping containers, electronics, and the deployment/recovery mechanism. A T-tail will ensure ample clearance for sensor deployment and recovery, with the added benefit of creating easier pitching for the plane. The wing airfoil will be a NACA 6412 with a chord length of 0.82 ft. and an aspect ratio of 6. The maximum lift coefficient is estimated to be 1.58.

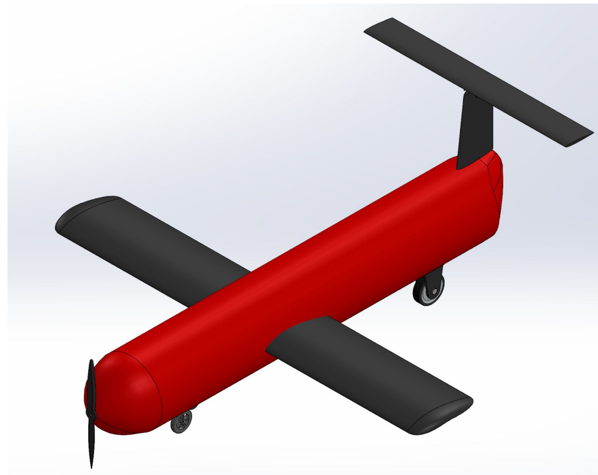
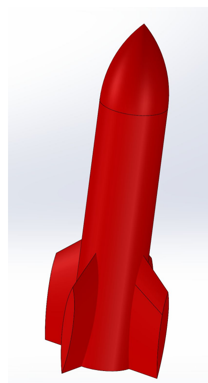


Figure 3.3.1: Preliminary aircraft design

The sensor body, pictured in Figure 3.3.2, is composed of a hollow cylinder with a 4 in. diameter and a length of 16 in., a hollow hyperboloid, and 4 fins to ensure aerodynamic stability. The drag coefficient of the sensor is estimated to be 0.13. The sensor lights will be instituted via a modified Dimension Engineering DELight Starter Kit, which allows for custom light sequencing. The sensor will be attached to the deployment mechanism in the aircraft via a tow cable, which is connected to the aircraft's receiver. Six different lights will be attached to the sensor. The lighting mechanism will be powered by a 1200mAh NiMH battery contained within the sensor.



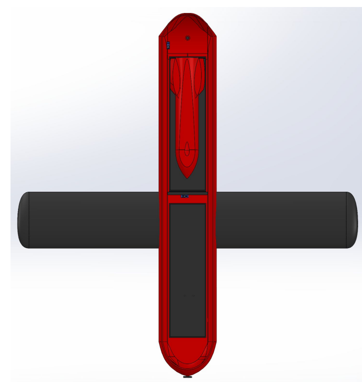


Figure 3.3.2 (left): Sensor

Figure 3.3.3 (right): Shipping containers and deployment/recover mechanism in fuselage

Two 6.35 in. by 6.35 in. by 23.30 in. sensor containers will be stored in the fuselage as shown in Figure 3.3.3. The deployable sensor is positioned at the back of the plane, above the release door. The door is connected to two cables and depicted in Figure 3.3.4. Servos will loosen the cables and allow the door to open; the sensor will deploy from the aircraft due to the 2° slope beneath the sensor and pressure differences. Once extracted, drag pushes it to full deployment. The sensor will be retrieved by a servo-winch system.

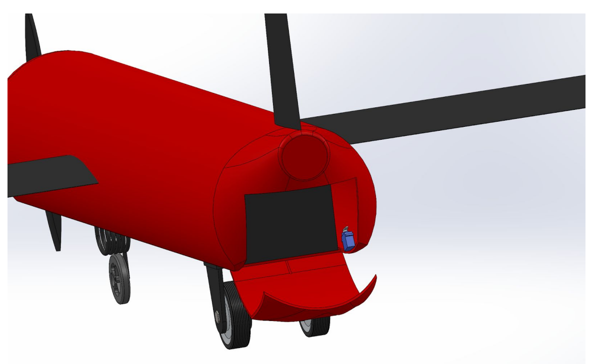


Figure 3.3.4: Payload door

Given the aircraft's projected dimensions, we will use a brushless Scorpion HKIII-5020-520 motor with a 120A ESC, a 15 in. by 10 in. Master Airscrew Glass Fiber Reinforced Composite propeller, and two Turnigy 5000mAh 5S 20C LiPo battery packs in parallel to meet the mission requirements. This configuration is expected to provide over 10 minutes of flight time and a satisfactory thrust-weight ratio, ensuring a maximization of Mission 3 capabilities.

4.0 – Manufacturing Plan

The team's manufacturing flowchart can be found in Figure 4.0. Manufacturing is designed to be an iterative process, with test data utilized to optimize subsequent designs. For the preliminary prototype, the fuselage will be manufactured using molded carbon-fiber sheets and epoxy. The process will be carried out using MDF boards shaped with a CNC machine, which allows for a strong, single-shell, double-layered body. The wingtips will be made of laser-cut hardwood; the internal foam board ribs will be cut out and covered with MonoKote to develop a lightweight, low drag airfoil. Two carbon fiber spars will bridge the wings and fuselage to attach the wings, while a single carbon fiber spar will be used to attach the tail. The spars will be attached to the fuselage using a combination of bolts and epoxy. Cyanoacrylate adhesives will be used to secure servos for control mechanisms. The sensor will be made out of hollow foam coins that are glued together and covered with Monokote. The containers will be manufactured out of foam panelling with carbon fiber frames along the edges and various glues to support the stress of impact. They will be inserted into the fuselage through a cutout hole in the top of the fuselage and restrained by geometric hard limits and fasteners.

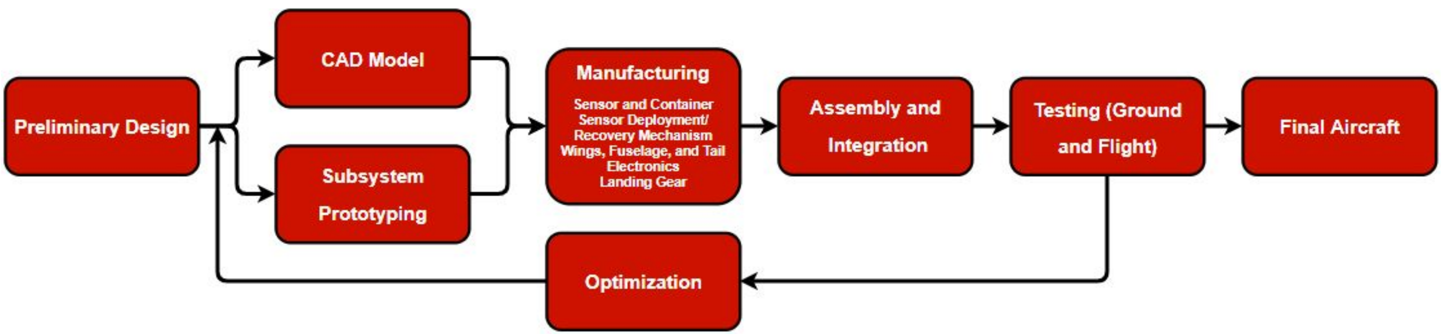


Figure 4.0: Preliminary manufacturing flowchart

5.0 – Test Planning

Validation of the simulation data will be the first priority in the testing process. Wind tunnel testing will be performed on a scale model of the final aircraft. This will serve to validate the XFLR5 data and Solidworks simulations used to determine the optimal wing and tail dimensions. Several tests will be conducted to validate the propulsion system's viability and safety. Battery discharge tests will be carried out to ensure that their performance coincides with the manufacturer's claims. Static thrust tests will be conducted to ensure that the motor thrust generated agrees with the simulated value, as well as to test how the entire electronics system performs in near-flight conditions. Lighting mechanism tests will be conducted by assembling the mechanism components and ensuring that lights activate and flash in accordance with the programmed sequence. The sensor lights will also be tested to ensure high visibility and reliability in flight.

The strength of the production wing will be evaluated through the wing-tip test. The sensor deployment and recovery mechanism will be subjected to several loading and wind conditions to ensure in-flight reliability. The shipping container restraint system will be tested by subjecting the fuselage to differing vibrational patterns. The landing gear will be impact tested to ensure no damage in the event of a hard landing. Center of mass tests will ensure proper weight distribution.

Once all subsystems have been adequately tested, a prototype will be manufactured and flown to test the aircraft's performance during all missions. In-flight performance of the sensor deployment and recovery mechanism, as well as its effect on the aircraft's center of mass, will be closely monitored. Sensor visibility will also be scrutinized. Pilot feedback will be taken into account and examined before constructing the final aircraft.

Ghulam Ishaq Khan Institute of Engineering Sciences & Technology

2020-21 AIAA Design/Build/Fly Design Proposal

1. EXECUTIVE SUMMARY

This proposal summarizes the planned design of a UAV with a towed sensor by Team Invictus of the Ghulam Ishaq Khan Institute of Engineering Sciences and Technology in response to the American Institute of Aeronautics and Astronautics (AIAA) Design, Build, Fly Competition 2020-2021. This year's objective is to design, manufacture, and test an unmanned aerial vehicle (UAV) with a sensor suite that is capable of transporting sensors in shipping containers and conducting surveillance by deploying, operating, and recovering a towed sensor.

The aircraft can have a maximum wingspan of 5 feet and must be capable of taking off within 100 feet take-off distance. It must be able to carry a maximum number of payloads in the form of a shipping container with a sensor as well as shipping container simulators of the same size and weight. Additionally, the aircraft must be capable of deploying and retrieving the sensor on a towline from inside the aircraft and the sensor must have a minimum diameter of 1in and a minimum length-to-diameter ratio of 4.

From preliminary analysis, the team has come up with a balsa monoplane configuration with a 5-foot wingspan, aspect ratio of 6, T-tail empennage reinforced with a carbon fiber rod, and tail-dragger landing gear. The aircraft has the capacity to carry 4 shipping containers and the sensor has a diameter of 1.5in and length of 10in with fins for stabilization. The deployment and retrieval mechanism will be implemented through a removable winch system tethered using a nylon fishing wire and controlled with a separate transmitter.

2. MANAGEMENT SUMMARY

2.1 Team Organization and Skills

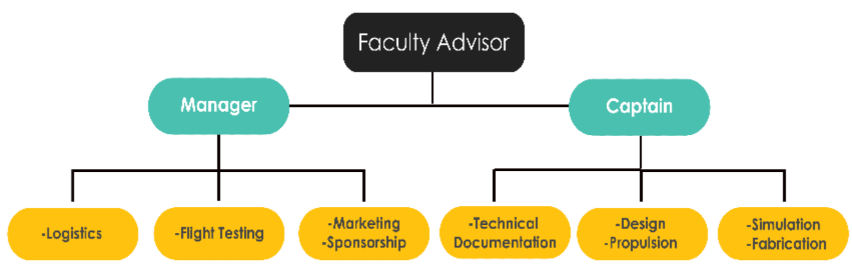


Figure 1 Hierarchy of Team Invictus

Team Invictus is a team of undergraduate students from the GIK Institute, arranged in a well-defined hierarchy. The team is overseen by the Faculty Advisor, acting as a bridge between the team and university administration as well as providing expert advice throughout the design and fabrication phase. The student team is headed by the Team Captain, who is responsible for the technical divisions, including design, manufacturing and technical writing. The Team Manager ensures smooth running of the team, including overseeing the finances, team discipline and administrative tasks. The team itself consists of 6 departments, each headed by junior year members in charge of a group of sophomores and freshmen. The members are selected after a rigorous recruitment process, which ensures the team maintains a constant stream of talent. The senior members have an assigned responsibility to pass on their knowledge, ensuring that the team can carry on its legacy each year. This year proved to be an additional challenge for the team since we had to work virtually so far due to COVID-19. As such, the team has additionally incorporated a digital platform to collaborate with team members from all over the country. Virtual and physical meetings were held weekly to discuss updates, ensure timely completion of tasks and formulate future plans. A description of each department and the hierarchy followed are given in Table 1 and Figure 1 respectively.

TEAM DIVISION	ROLE	SKILLS
Team Advisor	Faculty member of the institute, overseeing the team's performance.	Must have the required skills and knowledge to empower the team members
Team Captain	Senior year student leading the team and overseeing the technical aspects.	Must be sound in all technical aspects and have good leadership skills.
Team Manager	Senior year student responsible for the financial and administrative aspects of the team.	Must have good managerial and team building skills.
Documentation	Composing and compiling the proposal and design report.	Must have great technical writing skills.
Design/Propulsion	Designing and determining the optimal propulsion of the aircraft.	Must have the knowledge of aerodynamics, and the mechanical mechanisms of the aircraft.
Simulations	Constructing CAD models and running analysis of the aircraft.	Must be experienced users of the CAD/CAM and analysis software.
Testing	Running tests on the aircraft and its sub-systems.	Must have experience with flying electronic aircrafts and handling multiple testing machines.
Sponsorship/Marketing	Arranging potential sponsors and developing marketing strategies.	Must have great communication skills and knowledge about multi-platform marketing.
Fabrication	Manufacturing the aircraft.	Must have the knowledge of the mechanical and electrical mechanisms.
Logistics	Planning and managing the logistics from Pakistan to USA.	Must have basic understanding of logistical aspect of supply chain.

Table 1 Sub-Team Description

2.2 Schedule

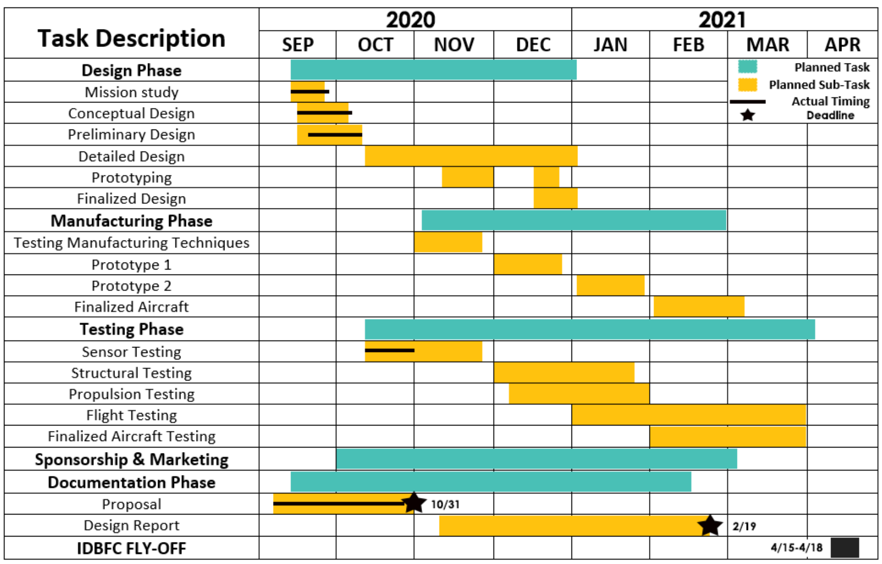


Figure 2 Gantt Chart

2.3 Budget

This year's budget was chosen after considering the design, revised prices, and cheaper alternatives. The team has secured a sponsor for fabrication materials from K.B Sarkar & Co. The sponsorship team is further contemplating numerous strategies to attract suitable sponsorship opportunities and hopes to secure further corporate sponsors similar to the past (CBL, MCB AH). The GIK Institute provides additional financial support along with manufacturing equipment and machines. Table 2 gives a comprehensive breakdown of the budget.

#	Item	Quantity	Cost	
Propulsion & Electronics				
1	Motor	1	$60.00	
2	ESC	1	$30.00	
3	Batteries	2	$80.00	
4	Propellers	2	$15.00	
5	Servos	7	$50.00	
6	Transmitter/Receiver	1	$100.00	$335.00
Fabrication				
7	Balsa	30	$130.00	
8	Carbon fiber rods	5	$30.00	
9	Monokote	5	$100.00	
10	High density foam	1	$10.00	
11	Adhesives	12	$20.00	
12	Fasteners	20	$10.00	$300.00
Out-sourced Manufacturing				
13	3D printing	-	$100.00	
14	CNC Laser cutting	-	$300.00	$400.00
Travelling				
15	Air fare	-	$6,000.00	
16	Air freight	-	$500.00	
17	Residence and food(5 nights)	-	$1,800.00	$8,300.00
			Grand Total	9,335.00

Table 2 Budget Breakdown

3. CONCEPTUAL DESIGN APPROACH

3.1 Mission Requirements

At the fly-off site, the competition has three flying missions and a ground mission. Brief overviews of the mission objectives and design parameters are given in Tables 3 and 4.

Mission	Objective	Time Limit	Payload
1	3 Laps Flight	5 minutes	None
2	3 Laps Flight	5 minutes	Maximum containers
3	Maximum # of Laps	10 minutes	Sensor with deploying and recovery mechanism
Ground Mission	-Drop test of the shipping container. -Loading and unloading of payload. -Demonstration of flight controls and sensor deployment and retrieval mechanism.	None	-Maximum shipping containers for M2 demonstration -Sensor with deploying and recovery mechanism for M3 demonstration

Table 3 Mission Objectives

Design Parameters	Motivation
Speed maximization	Mission time *inversely* related to M2 score and number of laps *directly* related to M3 score
Payload maximization	Number of containers *directly* related to M2 score
Sensor length and weight maximization	Sensor length and weight *directly* related to M3 score

Table 4 Design Parameters

3.2 Preliminary Design & Sensitivity Analysis

Based on the selected design parameters, the team came up with a list of potential design configurations, shown in Table 5. The best in each subsystem (shaded) was selected based on weighted criteria to form a final preliminary design, shown in Figure 4. The sensor deployment mechanism, shown in Figure 6, consists of a removable sliding panel with the winch and motor permanently attached to it that fixes into grooves on the fuselage wall. The sensor itself has fins on its trailing edge to stabilize it during flight as well as a sharp leading point to reduce drag. The back panel will be hinged to drop the sensor when opened while the top panel will be hinged to allow the containers to be placed into the fuselage. With a wing loading capacity of 15 oz/ft^3 and a reasonable estimate for the Reynold's number, the team opted for a flat-bottomed airfoil due to higher stability and control.

Design Aspect	Presented Configurations			Motivation
Wing Location	Top	Middle	Bottom	Maximizing Containers Compartments, Minimizing Payload Obstruction
Wing Sweep	Straight	Forward	Backward	Easy Fabrication and Aerodynamics Stability
Empennage	Conventi-onal	T-Tail	H-Tail	Strength, Less Interference, Better surface control
Landing Gear	Skids	Tricycle	Tail Dragger	Easy Fabrication, More Strength
Container Location	Behind CG	On CG	Beyond CG	Stable Location, CG Location
Container Loading	Top	Bottom	Side	Smaller loading time, Easy fabrication
Sensor Deployment	Top	Bottom	Rear	Less/No Interference, Stable Deployment & Retraction
Sensor Towline	Thread	Fishing Line	Rigid	Strength, Weight, Easily available

Table 5 Design Matrix

The purpose of a sensitivity analysis was to pave a trajectory for design optimization as well as maximization of expected mission score. Specific design parameters affecting M2 and M3 were varied while keeping the other parameters constant. The results yielded are shown in Figure 3. Thus, it can be concluded that the team's main aim must be to maximize the M3 score since all three M3 parameters significantly affect total score.

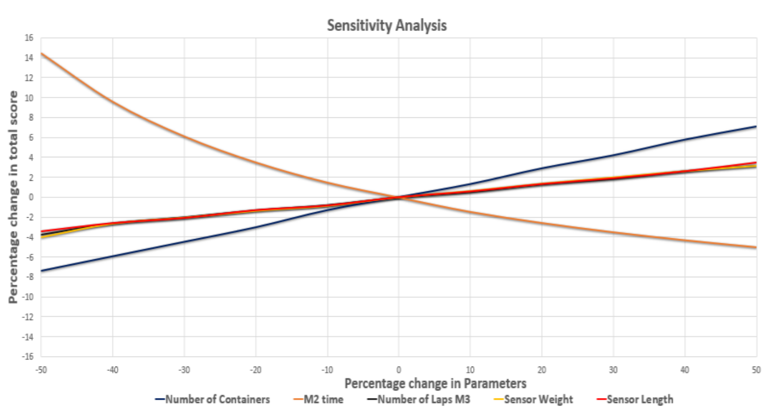
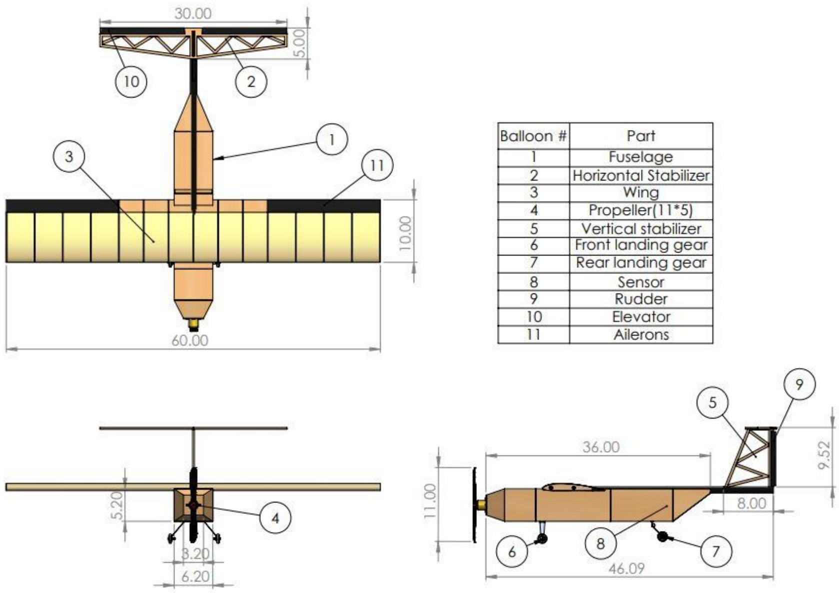


Figure 3 Sensitivity Analysis



Balloon #	Part
1	Fuselage
2	Horizontal Stabilizer
3	Wing
4	Propeller(11*5)
5	Vertical stabilizer
6	Front landing gear
7	Rear landing gear
8	Sensor
9	Rudder
10	Elevator
11	Ailerons

Figure 4 UAV Schematic & Dimensioning (all dimensions in inches)

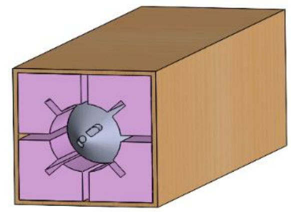


Figure 5 Sensor Container

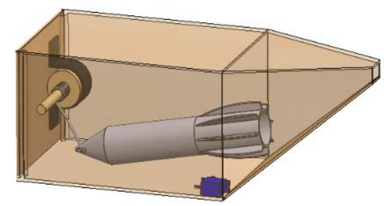


Figure 6 Sensor Deployment & Retrieval Mechanism

4. MANUFACTURING PLAN

4.1 Preliminary Manufacturing Plan

Prior to finalizing our UAV, several materials were subjected to tests with different constraints to find the most suited material for our aircraft. Preliminary results and research recommended the use of balsa wood, along with jumbolon reinforcements and carbon fiber rods for spars. Bulk heads would be strategically positioned on the critical areas of the aircraft to avoid damage, especially during landing. The entire manufacturing plan is divided into multiple steps, summarized in Figure 7. This can further be described in phases, where Phase 1 refers to the procurement of the raw materials. In Phase 2, laser cut custom ribs made from balsa will be procured for the aircraft, fuselage walls and empennage. Simultaneously, jumbolon would be cut to dimension, and sensors and bulkheads would be 3-D printed to get a smoother surface finish to reduce drag on the sensor and allow for more dimensional accuracy and precision. Phase 3 defines the assembly of the aircraft. All the parts will then be combined together and strengthened with epoxy, super glue and an assortment of mechanical fasteners. The 3in x 3in x 10in container for the sensor will be made from balsa with jumbolon padding inside, as shown in Figure 5, to dampen the impact on the sensor during the drop test in the Ground Mission.

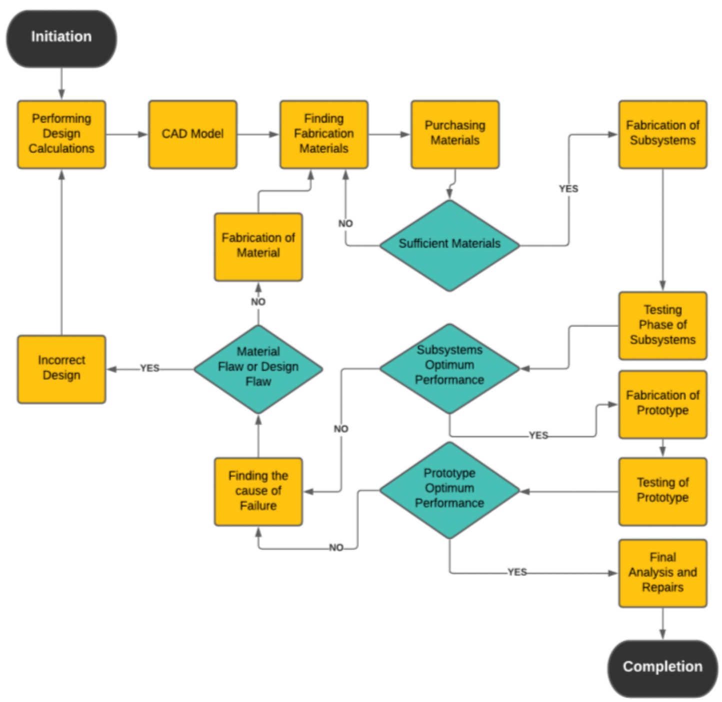


Figure 7 Manufacturing Flow

4.2 Critical Processes and Technology Required

Figure 8 shows the iteration process followed for the manufacturing of the aircraft. The use of laser cutting machines would be employed to manufacture the wign ribs with a greater accuracy as compared to manually cutting them. It reduces the time spent by the team during the fabrication and allows for more time to be spent on the testing phase. The bulkheads and sensor housing will be 3-D printed using PLA+, as shown in Figure 9, since it is affordable, lightweight, and strong. Balsa wood is a very common material amongst RC hobbyists due to its lightweight characteristics, outstanding strength-to-weight ratio, and durability while Jumbolon acts as a great padding material, and protects the aircraft from damages and allows safe storage for the electronics without significantly affecting the weight of the aircraft. Since the aircraft's weight during flight is countered through lift, the wings will be reinforced with a carbon fibre spar to improve structural performance. Furthermore, monokote will be used to cover the wings and stabilizers. It has negligible weight and, with the aid of a heat gun, can easily take the shape of the surface it is being applied to. Due to its smooth surface, it was found to keep drag on the control surfaces to a minimum and with the unlimited color choices, it adds an aesthetic element to the aircraft.

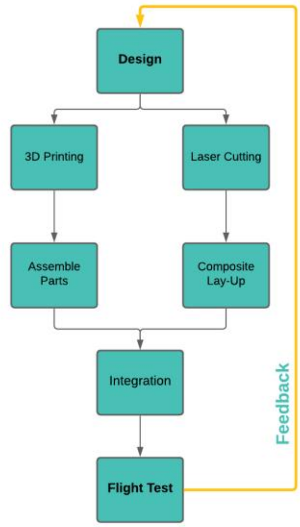


Figure 8 Critical Process & Technologies

Figure 9 Partially Manufactured Sensor

5. TESTING PLAN

The testing plan is in place to ensure that the aircraft is safe to operate at all times. The performance and reliability of control surfaces and sub-systems mechanism will be analysed to reduce any structural or performance lapses. Furthermore, the sensor's deployment and retrieval system will be tested for desired output criteria. The aircraft fuselage and landing gear will also be tested as per standards for structural integrity. Finally, the aircraft will be subjected to flight tests to simulate missions and acquire real-time data along with the pilot's feedback to trim the aircraft for the contest. Table 6 represents the factors and objectives of the multiple tests to be performed.

Phase	Factor	Test	Objective
Component	Motor and prop Combination	Motor test stand	Check static thrust, propeller rotation ratio
	Battery	Motor test stand	Check current draw, voltage, and battery life
	Wing	Wingtip test under +/- 5G loading	Conclude wing withstands loads during flight and landing
	Sensor and compartments restraint	Load stability by hand	Conclude high structural rigidity and sturdiness
	Sensor deployment/retrieval structure	Test in a wind tunnel	Verify mechanism successfully deploys/retrieves sensor
	Container material	Drop test	Conclude it will not break and withstand damage
	Landing gear	Impact load test and drop test	Conclude it sustains impactful landings
Ground	Control surfaces	Controller controls	Verify all functions in working condition
	Centre of gravity	Wingtip test	Verify CG is in the desired position
	Loading and unloading	Timed tests	Minimum for a sensor
	Directional steering	Taxiing	Verify steering controllability
Flight	Flight parameters	Wind tunnel test	Conclude critical angle of attack, stall speed, and drag
	Speed	Stopwatch	Conclude the aircraft's minimum lap time
	Stability	Experienced pilot's visual cues	Obtain pilot's recommendations and feedback
	Take-off distance	Measuring the take-off length	Ensure aircraft take-off distance is in desired range
	Sensor subsystem operability	Deployment and retrieval of sensor	Ensure sensor does not collide with control surfaces

Table 6 Testing Plan

University of Alabama at Birmingham
2020-2021 AIAA Design/Build/Fly Design Proposal

1. Executive Summary

This submission represents the University of Alabama at Birmingham's proposal for the 2020-2021 AIAA Design-Build-Fly Competition. The objective for this year's competition is to design and build a sensor-towing UAV that will also transport sensors in shipping containers. The aircraft must have a maximum wingspan of 5 ft, weigh no more than 55lbs, and takeoff within a maximum length of 100 ft. In addition, the sensors must have a minimum diameter of 1.0 inch with a minimum length to diameter ratio of 4 and be aerodynamically stable during remote deployment, operation, and retrieval. The deployment length must be 10 times the sensor length, and the sensor must have a minimum of 3 LED's. Furthermore, the sensors must be housed in individual shipping containers that are capable of protecting the sensor when dropped on all sides from a height of 10 inches.

To accomplish this objective, UAB formed an interdisciplinary team of student-engineers to conduct an analysis of the competition parameters and design an aircraft optimized for these missions. An analysis of the mission parameters revealed that the best design will be dependent on a fast ground mission and average lap time. With this in mind, the team will focus most of its efforts on designing a lightweight, fast aircraft that is easy to load. Therefore, the design will encompass a single-motor conventional high wing aircraft that will carry a total of 10 lbs of payload, and tow a sensor that is launched from the rear of the plane with assistance from a set of rear-mounted grid fins and two cables connected laterally to create tension along the longitudinal and latitudinal axis and promote LED sensor aerodynamic stability. The electrical team will determine the optimal thrust for target weight and integrate the communication and control systems for the aircraft. The mechanical group will optimize the external geometry using conventional design techniques and simulations, design the required payload systems, select appropriate materials, and determine a manufacturing method that will result in the lightest possible empty weight for the target payload.

2. Management Summary
2.1 Organization Description

Table 2.1 Organization Sub-Team Information

Sub-Team	Members (Classification)	Roles	Required Skills
Wing and Empennage	Jordan Fuse (ME) Akash Patel (ME) Sean Dean (ME) Wesley Zou (ME) Michael Bamberg (MSE)	• Select the airfoil and conduct trade studies to determine the best wing and tail configuration • Develop a constraint diagram to determine optimal horsepower and wing loading • Design, test, and optimize the aileron, rudder and elevator controls	• Proficiency in CAD,FEA, MATLAB, and X-Foil • Understanding of aerodynamic principles • Proficiency in structural analysis
Fuselage/Landing Gear/Power Supplies and Drives	Brady Baldwin (ME) Peyton Barber (ME) Preston Dierking (ME) Jacob Marshall (ME)	• Optimize fuselage to carry max payload with minimum drag • Design remote activated door for sensor to enter and exit the UAV • Perform structural analysis on fuselage and landing gear to prove UAV is balanced • Design mechanisms to connect airfoil and landing gear to fuselage	• Proficiency in CAD, FEA, CFD, and MATLAB • Understanding of aerodynamic principals • Understanding structural analysis and machine design principals
Sensor Storage Container	Cameron Chandler (ME) Jonah Morgan (ME)	• Design the shipping container for the deployable sensor • Ensure container adequately protects the sensor from sudden impact	• Proficiency in CAD,FEA, and CFD
Electric Propulsion and Controls	Josiah Schaeffer (AE/ME) Joe Wong (EE) Ian Yuen (ME/CS)	• Propeller Design and Specifications • Electric Circuit/Motor Type Research • Power Supply Requirements (collaboration with mechanical sub-teams) • Flight Control Design/Optimization Pertaining to the Circuitry Aspect (collaboration with the Wing and Empennage)	• Familiarity with electrical systems and basic circuit components pertaining to the motor and controls. • Knowledge in power, voltage, and current calculations. • Understanding of physics for propulsion force computations and proficiency with eCalc software
Sensor Deployment, Retrieval, and Stability Mechanism	Tabitha Berry (ME) Spencer Ward (ME) Jordan Wilbanks (ME)	• Develop the mechanism required for deploying and retracting sensors in accordance with M2 and M3 guidelines. • Integrate sensor subsystem with aircraft main structure design while maintaining optimal aircraft performance.	• Mechatronics, CAD • Strong understanding of Machine Design Principles and structural analysis
Treasury/Media	Jordan Fuse (ME) Cameron Chandler (ME) Tabitha Berry (ME) Jacob Marshall (ME)	• Fundraise, budget plan, and handle purchases • Run the team's social media accounts and websites • Produce well-designed graphics and promotional content	• Proficiency with design and photo editing software • Experience with financial control and budgeting • Proficiency in marketing and communication

The organizational structure for UAB's 2020 Design-Build-Fly team consists of 18 undergraduate students and 3 faculty advisors. Table 2.1 shows each sub-team category, names every sub-team member and engineering discipline, defines sub-team roles, and lists required skill sets. Undergraduate students come from different academic years, engineering disciplines (ME, EE, MSE), and technical backgrounds. This results in a variety of team dynamics and contributions, which, in turn allows for the progression of the team's fluidity and experience.

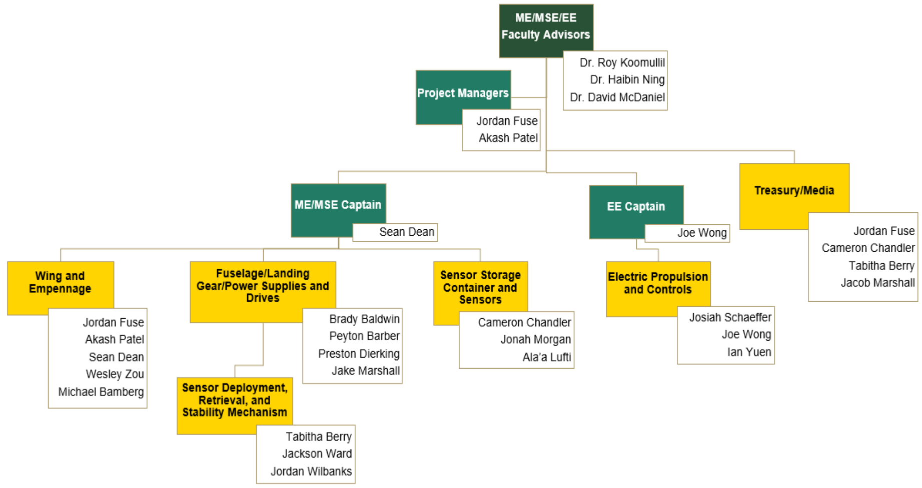


Figure 2.1 Organization Structure

Figure 2.1 depicts the organizational structure and outlines the chain of command. Faulty advisors provide guidance, promote healthy discussion, and monitor their designated sub-team's development. The project managers oversee all design activities, competition submissions, budgeting, and scheduling, while captains manage their sub-team and communicate with the project managers to submit deliverables on schedule. Team members are distributed between the 6 sub-teams based on skill and preference. Weekly meetings are used to collaborate on the project's development, team's performance, and design complications. Decisions and weekly goals are established during each meeting, and if any unresolved issues arise, project managers work with faculty advisors to find a resolution. The design schedule for the project is shown in Figure 2.2. The major milestones of the competition are denoted by stars. Outside of competition deadlines and fly-off, three flight tests are scheduled prior to the competition. The Gantt chart conveys the scheduled workload and ensures that team goals are achieved on time so that the UAV can be assembled in a logical sequence.

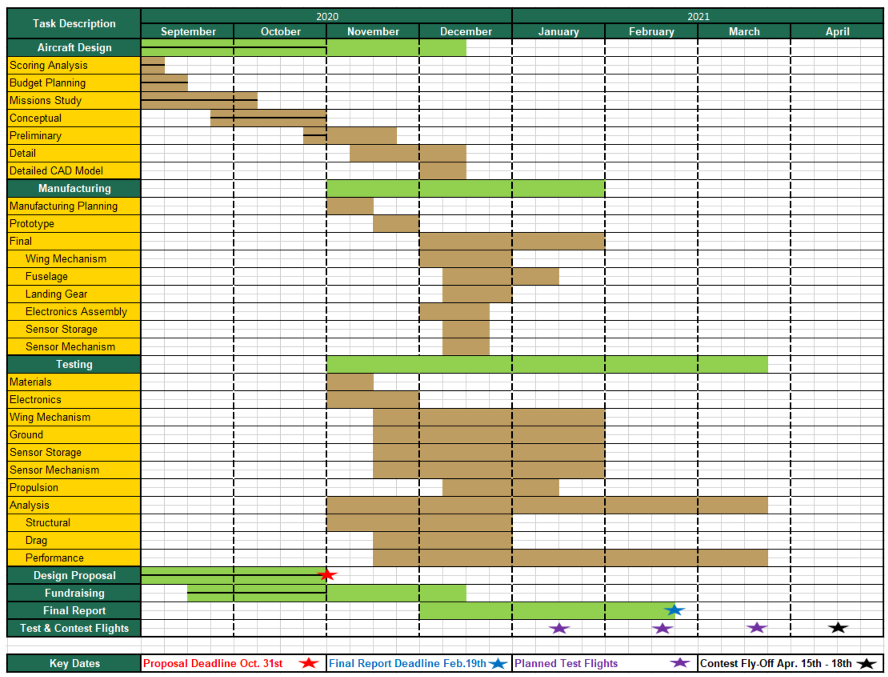


Figure 2.2 Design Schedule

2.2 Budget

The budget was developed based on a series of quotes from manufacturers, travel companies, and other entities. Travel expenses were based on eight people and five hotel rooms for 4 nights. Expenses for materials that meet the parameters for the UAV are included with pricing from their respective manufacturers. Funding will be acquired through sponsors via a UAB FIRE donation account, UAB's AIAA student branch account, and from the UAB School of Engineering. The project managers are authorized to spend AIAA student branch account money through the Branch chair, and faculty chairs are authorized to spend the UAB School of Engineering's funds. FIRE account sponsors will receive weekly updates on project status via the team's website newsletter. The budget is shown in Table 2.2 and is primarily dominated by travel expenses.

Table 2.2: DBF Budget

Budget for Design Build Fly Competition							
Travel		Structural		Electrical		Miscellaneous	
Airline tickets	$3200	Carbon Fiber	$305	Fuel Cell	$470	Propeller	$30
Lodging	$2800	Epoxy Resin	$40	Motor	$340	Landing gear	$85
Per diem	$2000	Balsa wood	$40	Communications	$430	Kevlar shears	$50
		Mylar coating	$60	Servos	$42	Misc. materials	$130
		Nylon film	$10			Sensor parts	$115
Total	$8000	Total	$455	Total	$1282	Total	$410
Grand Total:	**$10,147**						

3. Conceptual Design

3.1 Sub – System Requirements

The mission for this competition is to build a sensor towing plane that is capable of remotely deploying and retrieving a sensor as well as transporting sensors in shipping containers around the designated course. This year's competition consists of one ground mission and three flight missions. Table 3.1 describes the missions and their corresponding scores, along with flight requirements and sub system requirements.

Table 3.1 Mission Requirements

Mission	Scoring	Mission Requirements	Sub-System Requirements
GM	$GM = \left[\frac{GM\_Time_{Min}}{GM\_Time_N}\right]$	➢ Demonstrate containers protect sensors ➢ Timed loading of aircraft with max sensor/container payload in M2 and sensor deployment mechanism for M3 ➢ Pilot demonstrates that flight controls are active and sensor deployment mechanisms are functioning	➢ Stowing system and sensor deployment mechanisms should be designed for ease of installation
M1	$= 1.0$	➢ No payload for this mission ➢ Complete 3 laps in 5 minutes ➢ Takeoff length is 100 feet ➢ Must complete successful landing	➢ Lightweight and fast to maximize score
M2	$= 1.0 + \left[\frac{\left(\#Container/Time\right)_N}{\left(\#Container/Time\right)_{Max}}\right]$	➢ Mission payload is the sensor in shipping container and the deployment and recovery mechanism ➢ Core requirements same as M1	➢ Scoring impacted by flight speed, fuselage storage capacity, gross weight, and payload design ➢ Sensor container transparent enough to view LED's in sunny weather ➢ Design successful remote sensor deployment and retrieval mechanism
M3	$2.0 + \left[\frac{\left(\#Laps \times Sensor_{Length} \times Sensor_{Weight}\right)_N}{\left(\#Laps \times Sensor_{Length} \times Sensor_{Weight}\right)_{Max}}\right]$	➢ Mission payload is a sensor and the deployment and recovery mechanism ➢ Core requirements same as M1 except flight window is 10 minutes ➢ Sensor deployed prior to first 360˚ turn and fully retracted before final 360˚ turn	

3.2 Sensitivity Study

A sensitivity study determined which aircraft features were most critical to design performance. A MATLAB® code of the mission tested different variables to observe how they impacted score. It is apparent from Figure 3.1 that the two most important variables are the ground mission time and the average lap time. The number of containers is the next critical score factor, and sensor weight and sensor length are tied for the least impactful. This analysis suggests that a faster aircraft that is easier to load will outperform a larger aircraft that can carry more or longer containers. Therefore, the design should be optimized for speed and ease of loading. The design will not be optimized to carry a large portion of sensors. After analyzing model data, the group decided to pursue a target maximum weight of 20 lbs. This was chosen based on the recommended mean power consumption given by the Electrical Engineering team working on the propulsion system.

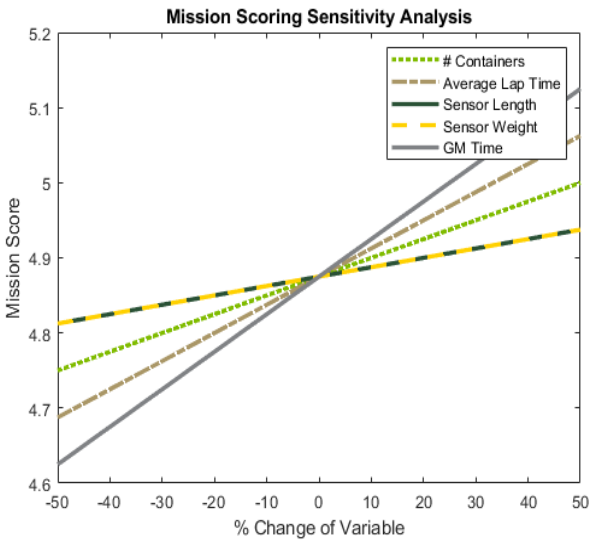


Figure 3.1 Score Sensitivity Analysis

3.3 Preliminary Design

The sensitivity analysis showed that gross weight should not exceed 20lbs, therefore empty weight should be reduced to maximize speed and enhance the score. Estimates show that the aircraft will have an empty weight of approximately 10lbs, thus allowing a max payload of up to 10 lbs for the sensors, storage containers, and towing mechanism. An iterative approach was used to develop a constraint diagram that determined the optimal wing loading (W/S) and thrust to weight ratio (T/W). The performance characteristics of the selected SD7062 airfoil, atmospheric properties at take-off and cruising altitudes, and stall speed were used in the development of the constraint diagram. In addition, a chord length of 1ft and a wingspan of 5ft was used to create the diagram based on the T/W for cruising airspeed, constant velocity turn, desired take-off distance, and rate of climb requirement as shown in Figure 3.2. The electrical team will use this diagram to analyze the optimal thrust to weight ratio and determine the best battery and propeller that will meet the competition requirements. The team decided to design a conventional, high wing UAV that's suitable for rear sensor deployment and towing as shown in Figure 3.3. The sensor will be a cylindrical design with rounded ends. It will deploy from the rear of the UAV, and use rearward-mounted grid fins for stability as depicted in Figure 3.4. These grid fins will be folded against the outer wall of the sensor in their storage position and will open perpendicular to the sensor during deployment and flight. The sensor deployment and retrieval mechanism will use torque via a single motor to release the sensor out of the back of the aircraft. This mechanism will feature two cables connected laterally, experiencing tension along both the longitudinal axis and the latitudinal axis, allowing the sensor to sustain stable flight with the LED's facing the ground.

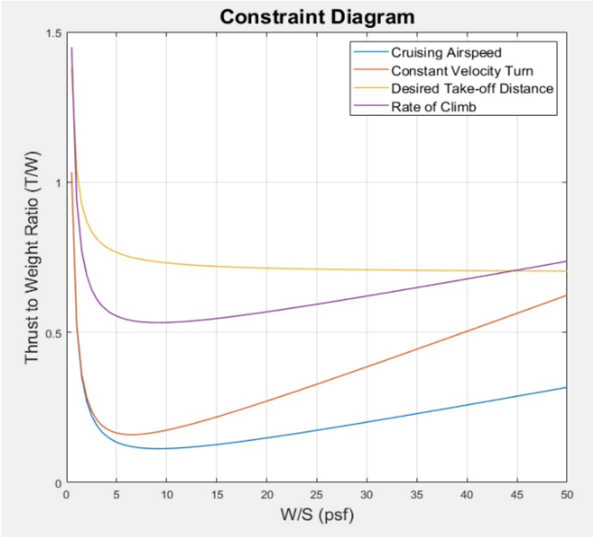


Figure 3.2 Constraint Diagram


Figure 3.3 Aircraft Conceptual Design

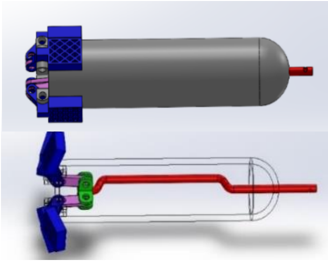


Figure 3.4 Towed Sensor

The spool associated with the mechanism is a design built to run on a single motor and operate the two tow lines from separate coiling mechanisms. The coiling mechanisms themselves will be 3D printed with a 2-inch diameter, both connected to a shaft that allows the motor to drive the mechanism. The mechanism will be located close to the center of gravity, in order to avoid a negative moment pulling up the nose of the UAV.

4. Manufacturing Plan

Once modeling and analysis produces a feasible geometry for the aircraft, prototypes of each major component will be tested for structural integrity and viability before being combined as shown in Figure 4.1. This two-phase manufacturing analysis approach will allow for the optimization of each element of the aircraft independently, and again once the airplane is assembled. Primary materials to be used for the airframe include bass wood, balsa wood, carbon fiber rods, extruded polystyrene foam (XPS), and continuous fiber reinforced polymer matrix 3D printed composites. The skin material will be a combination of fiber- reinforced polymer matrix composites, polyethylene terephthalate glycol (PETG), biaxially-oriented polyethylene terephthalate (BoPET), and polyethylene (PE) film. The quantity of carbon fiber composite parts will be limited by budget constraints, as carbon fiber is approximately ten times more expensive than balsa. Hand lay-up, vacuum-assisted resin transfer, CNC laser cutting, CNC milling, 3D printing, and thermoforming will be used to manufacture the aircraft and its cargo.

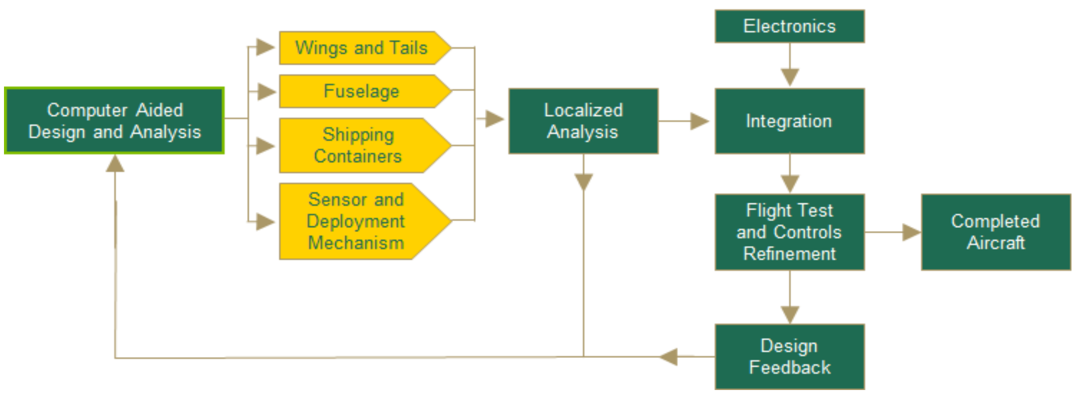


Figure 4.1 Manufacturing Flow Chart

5. Test Planning

Safety precautions will be the number one priority from the start of the testing phase until the conclusion of the competition. Each subsystem will be evaluated independently before being integrated into the final assembly. The structural elements will be tested for symmetry and robustness by multipoint balancing and simulated static loading. The propulsion system will be analyzed on a static thrust stand to monitor power consumption and propeller performance. The drag force on the towed sensor will be estimated using computational fluid dynamics. The sensor's aerodynamic stability and attitude will then be tested by simulating flight speeds using a motor vehicle. The sensor and shipping containers will be designed and tested against the ability to endure multiple impacts from being dropped at a height of 10 inches on all sides. The sensor deployment system will be assessed for power consumption and cycling without signs of fatigue. Once each sub-system is confirmed the aircraft will be completely assembled. The center of gravity will then be determined, and altered if necessary, for each mission's flight configuration. Pre-flight checks will be used to confirm proper operation of each control surface, the sensor deployment system, propulsion system, and communications. Initial flight testing is set to begin mid-January.