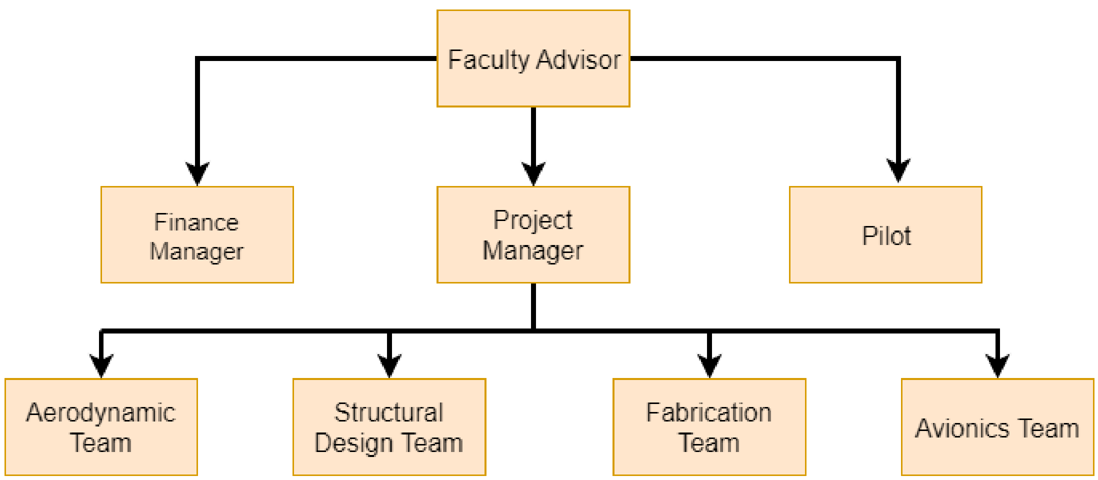
Team Saarang, Indian Institute of Technology Kanpur

EXECUTIVE SUMMARY

In response to 2018/2019 AIAA Design/Build/Fly competition, Team Saarang from IIT Kanpur, presents the following proposal for design and development of a multipurpose aircraft to support carrier operations.
To meet all the objectives required for the competition, our team is divided into subunits that focus on specific objectives based on the skills and experience of the team members. First, a comparative study based on design drivers was carried out to select the aircraft configuration. The preliminary sizing for the wing was done based on aerodynamic design and was refined after structural analysis. Novel mechanisms for reconfiguration and payload dropping will be implemented. The fabrication team uses their prior experience in aeromodelling to fabricate various prototypes during the course of development. Avionics team helps in controlling the aircraft during Mission 3 when center of gravity shift laterally due to dropping of payload.
Software like Ansys Fluent, Solidworks, Abacus, XFLR, Matlab, etc have been used for the design and structural analysis of the aircraft and various processes like lazer cutting, 3D printing, vacuum bagging, fiber moulding, etc. will be used for fabrication.

MANAGEMENT SUMMARY

The team is divided into sub units based on their skills and prior experience. The flow chart below presents the structure of the team and Table 1 gives the detailed roles played by each sub unit in the development.

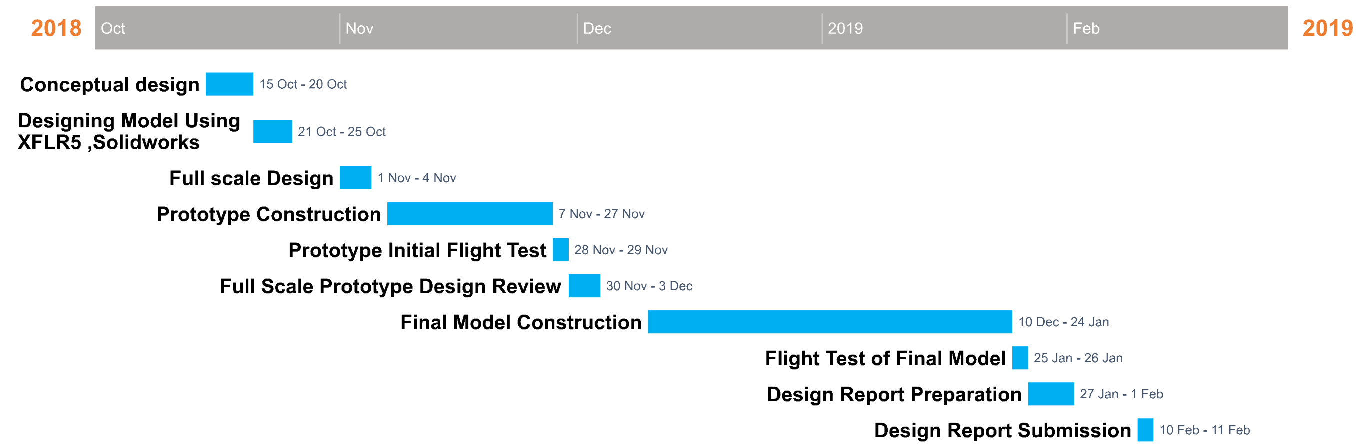


Team Layout

Tabel 1: Tasks and contribution of different sub units and team members

Faculty Advisor	Project Manager	Finance Manager	Fabrication Team	Aerodynamics Team	Avionics	Structural Design	Pilot
1.Guidance on Technical Issue **2.**Secure team funds, and work with University 3.Resolve issues with the institute	**1.**Distributes work among members **2.**Team progress update 3.Helps in technical issues	**1.**Estimates the budget of fabrication material **2.** Regulates the expenditure	**1.**Builds up models and prototypes for various tests **2.**Fabricates the final product	**1.**Performs fluid dynamic calculations through software **2.**Preliminary design based on aerodynamic coefficients	**1.** Installs electronics **2.**Installs and instruments autopilot for stability 3.Handles power requirements	**1.**Conducts structural analysis for various elements. **2.**Prepares structural design for the final aircraft	**1.**Conducts flight tests for various prototypes **2.** Provides insights to flight behavior of prototypes.

The timeline for the proposed plan to accomplish all the objectives is given below.



Proposed timeline with significant milestones

Table 2 : Budget Disstribution

S.No.	Item Description	Approximate. Cost
	Materials	
1.	Aircraft Material	$225
2.	Motor and Speed Controller	$170
3.	Propeller	$15
4.	Batteries	$165
5.	Servo motors,actuators	$200
6.	Adhesive	$120
7.	Nylon hinges,landing gears	$50
8.	Miscellaneous	$100
	Travel and Hospitality	
9.	Travel	$12,000
10.	Stay and Food	$750
	Total	**$13,795**

CONCEPTUAL DESIGN APPROACH

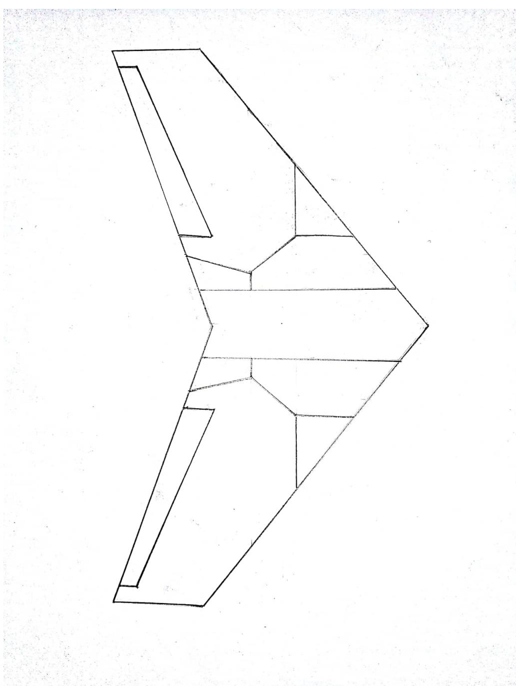
Configuration Selection: The team considered various configurations for the aircraft design and carried out a systematic study to decide the trade-off between various design drivers. The deciding parameter for the configurations was easy and quick reconfigurability of the aircraft from the stowed configuration to flight configuration. Therefore, simplicity and compactness was important and hence, flying-wing configuration was selected as the basic layout for the aircraft. The foldability of the wings would be implemented by folding the wing backward along the yawing axis of the aircraft. Table 3 presents the comparative trade off between various design drivers which are given in the first column. The weightage assigned to each design driver is given in the second column. Each configuration was scored comparatively and the final scores are given in the last row.

Table 3 : Design Drivers and Sensitivity Analysis

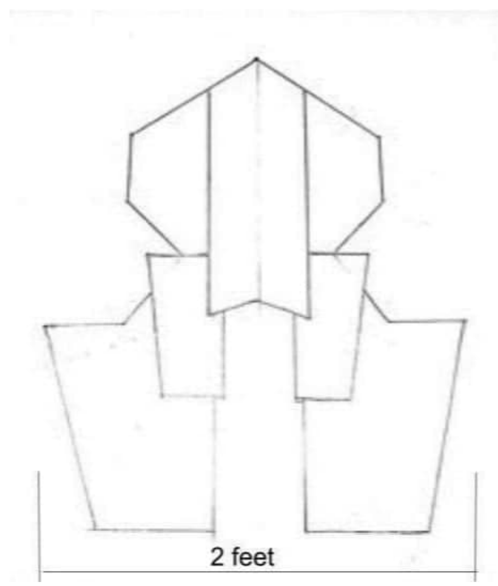
Features	weightage	Monoplane	Flying wing	Biplane	Rogallo
Empty weight	10	3	4	2	5
Payload (Capacity)	10	3	4	4	5
Stability	15	4	3	4	2
Speed	15	3	5	2	2
Ease of fabrication	20	4	3	3	2
Structural strength	15	5	4	4	3
Compactness	15	3	4	2	2
Total	100	365	380	300	275

Aerodynamic Design

The preliminary sizing for the wing was carried out using Xfoil analysis based on lifting line theory with an estimated weight from the prior experience in aircraft design and aeromodelling. Iterations would be performed to optimize the design to obtain maximum aerodynamic and structural efficiency. Currently, MH45 is being used as the wing airfoil due to high lifting capacity and low pitching moment for the first prototype design. The airfoil may be changed during the course of development as per the requirements. Tapered and swept planform was selected for the wing and the tips were given a negative twist for longitudinal stability. The fuselage for the flying wing will be placed below the wings to allow easy and undisturbed transition of the wings from stowed to flight mode.
The flight velocity was assumed to be approximately 10 mps, which is typically the velocity for similarly sized aircraft. XFLR was used for preliminary sizing, the final design will be based on analysis using Ansys Fluent and Abacus.



(a) Flight mode configuration



(b) Stowed Configuration

Fig. 1. Stowed Configuration

Mechanical Design

Novel mechanisms are required as per the mission requirement for remotely controlled reconfiguration of the aircraft, installation of rotating radome as well as the dropping mechanism for the missiles. Various methods will be considered for the different tasks of the mission requirements and experiments will be conducted to select the optimum mechanisms. The driving parameters for the mechanism selection are simplicity, lightweight, robustness and failsafe. Actuation is mainly provided through servo motors and mechanical locks will be installed for the folding wings.

Structural Design

The structural design was complicated due to the addition of folding mechanisms in the wing. Software, like Fusion 360, was used for calculating the loads on various components of the aircraft. Since the maximum bending moment is found at the root of the wing, the folding mechanism is installed at a distance from the root of the wing. The material selection for the airframe was performed through a series of strength test experiments for various load carrying members of the aircraft. For the first prototype, the spar consists of balsa wood sandwiched between carbon fiber. The number of layers of carbon fiber was decided through a code written by team members that considered the bending moment and the strength of structure to calculate the number of fiber layers.

MANUFACTURING PLAN

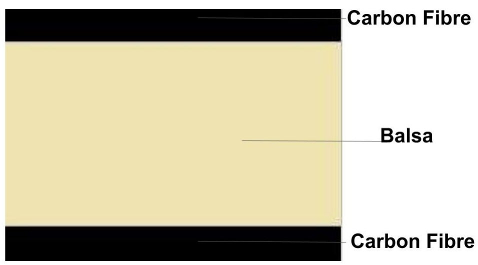
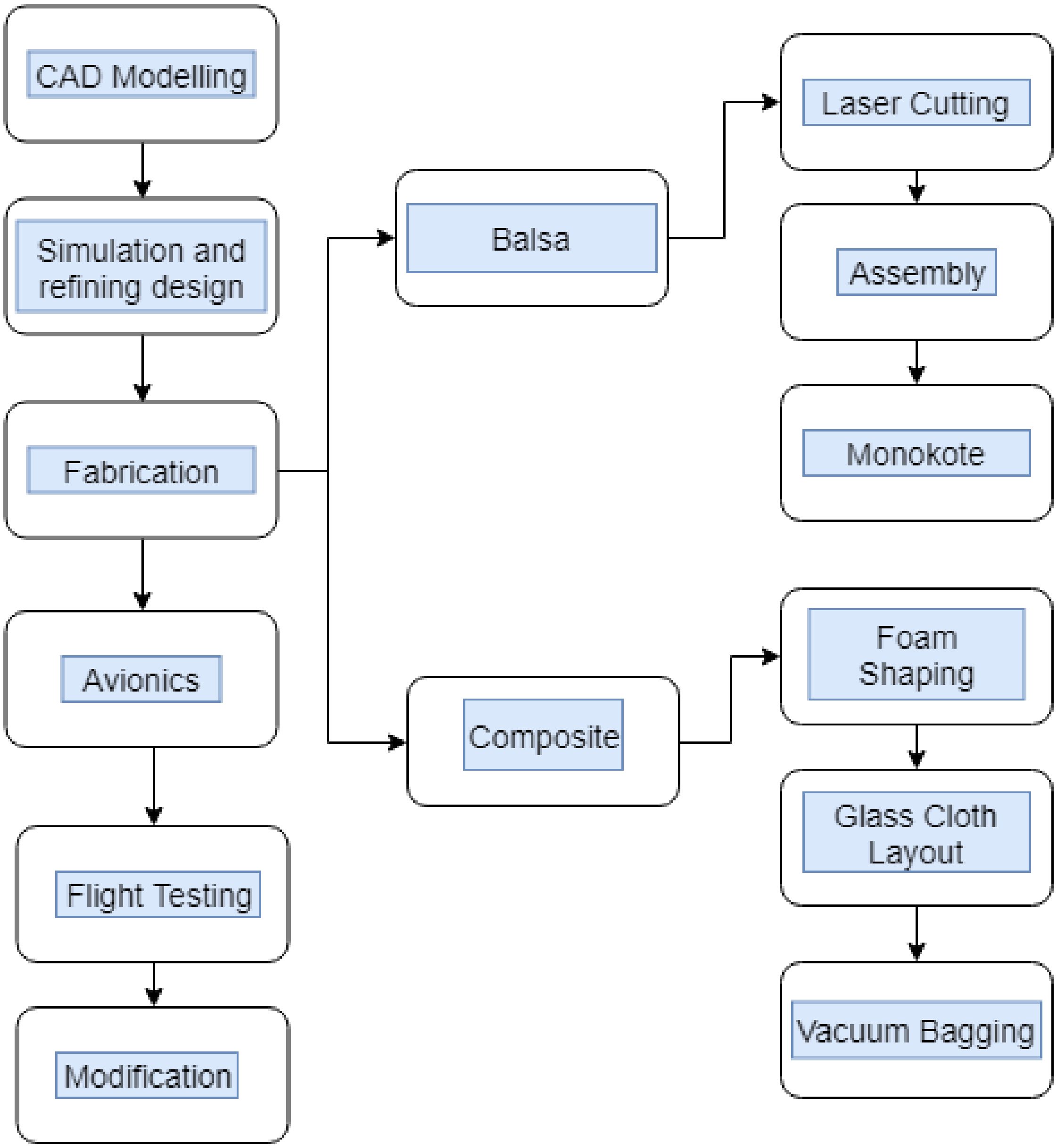


Fig. 2. Cross section of composite spar

The fabrication team consists of students who have prior experience in aeromodelling with a variety of material like balsa, styrofoam and composites. The primary material to be used for fabrication will be foam, balsa wood, fiberglass, carbon fiber, epoxy resins, and monokote. Various parts of the airframe will be fabricated using different material depending on the weight and strength requirement and ease of fabrication. The first prototype will have the foldable wings made of balsa wood covered with monokote. Balsa wood has been used to provide lightweight wings that can be transit easily during reconfiguration. The root of the wings that contain the actuators will be fabricated with composite material. It provides robust support for the actuators as well as the strong root of the wing where the maximum bending moment acts.
The spar has been fabricated using balsa wood and carbon fiber. The maximum shear stress is formed at the top and bottom of the spar, therefore, strong material like carbon fiber has been put up there while the central core is made of lighter material like balsa wood. The entire assembly is wrapped with a glass fiber to form a united structure. The fuselage will be made with balsa wood reinforced with composites that provides strength with lightweight structure.
The flow chart on the next page gives an outline of the manufacturing process to be followed in the development of the aircraft.

TEST PLANNING

A series of systematic experiments and tests will be conducted for individual sub systems as well as the final prototypes. The tests for sub-systems will check the remotely controlled reconfiguration mechanism which will finally be installed in the aircraft. The strength-tests will be performed for the load carrying members of the aircraft. Wingtip test, as described in the problem statement will also be conducted for various prototypes and the structural design will be upgraded based on the results. Various locking mechanisms will be tested and the optimum mechanism will be selected for the the final aircraft. The ground tests will also include testing of avionics installed for the control.
Besides ground tests, several flight tests will be performed, which are essential for an aircraft design. Model aircraft will be fabricated and flight tests will be conducted for the payload tests. The final prototype will be flight tested after fabrication and ground test of all the sub-systems. Modifications will be made, if required, to the design based on the results of flight tests. All the flight tests will be performed at the airstrip at Flight Laboratory, IIT Kanpur.
Electronics, propellers and design will be upgraded based on the results of actual test flight and experiments.


CAD Modelling
Simulation and refining design
Fabrication
Avionics
Flight Testing
Modification
Balsa
Composite
Laser Cutting
Assembly
Monokote
Foam Shaping
Glass Cloth Layout
Vacuum Bagging