KAK & KOKIL

A Concept & Design of Dual Drone Operational System

Final Year Design Project

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FINAL YEAR DESIGN PROJECT REPORT

This Report is Presented in Partial Fulfillment of the Requirements for the **Degree of Bachelor of Science in Computer Science and Engineering**

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September 17, 2025

APPROVAL

This Project titled **"A Concept & Design of Dual Drone Operational System"**, submitted by Mohitul Islam, ID No: 172-15-10221 and Sohag Baidya ID No: 203-15-14467 to the Department of Computer Science and Engineering, Daffodil International University has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Computer Science and Engineering and approved as to its style and contents. The presentation has been held on **17 September, 2025.**

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DECLARATION

We hereby declare that this project, titled "KAK & KOKIL: A Concept & Design of Dual Drone Operational System", has been carried out by us under the supervision of Dr. Abdus Sattar, Assistant Professor, Department of Computer Science and Engineering, Daffodil International University, and co-supervised by Nazmoon Nessa Moon, Associate Professor, Department of Computer Science and Engineering, Daffodil International University. We further declare that neither this project nor any part of it has been submitted elsewhere for the award of any degree or diploma.

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ACKNOWLEDGEMENTS

We are grateful to those who support us in so many ways, during the long developmental phase and the final stages of the project research paper.

Acknowledgements We would like to thank our revered supervisor, Dr. Abdus Sattar, Assi Professor and Coordinator, M.Sc. and program, Department of Computer Science and Engineering, Daffodil International University. His professional advice, ongoing encouragement, and constructive comments were invaluable in orienting this work. His hard work and attention to the highest level of achievement were always inspiring, and he'll be greatly missed as a mentor.

We also wish to thank Md. Sazzadur Ahmed for his assistance which was really very helpful during the most technically challenging phases of the project. His guidance, resources and ability to solve the now numerous "hurdles" that we had to go through were indispensable. His work improved the technical quality and productivity of our project very much.

We acknowledge with thanks to the faculties and staffs of the Department of Computer Science and Engineering of Daffodil International University for their support, co-operation and encouragement along this path.

Finally, we are truly indebted to our families for their patience, understanding, and non-stop moral support which has been more than invaluable throughout our research.

We owe a lot of thanks to everybody who is involved in contributing to allow this kind of project be possible.

ABSTRACT

In this report, a design, development, and integration of a two-drone Unmanned Aerial Vehicle (UAV) system is given, composed of Kak and Kokil drones. Kak is a long-range reconnaissance and surveillance hybrid propulsion UAV, and Kokil is a smaller, tactical quadcopter, that specializes in operations at short ranges. The main aim of this project is to overcome the problem of designing UAVs that can be versatile to the military and civilian life because of balancing between long endurance and agilities. The Kak UAV employs a hybrid propulsion system to enable the switching of the jet engine to an electric one or vice versa to best suit high speed missions or stealth maneuvers. Kokil, an agent of Kak, is prepared to do quick reconnaissance of restricted or sensitive places. The engineering issues that had to be overcome included integration of payload, flight stability and power management. The dual UAV system incorporates both of these platforms to produce a versatile and affordable system to use in a wide range of mission profiles. Another technical aspect covered in this paper is the technical characteristics of the Kak and Kokil UAVs, their operational deployment and possible use in military and humanitarian missions.

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Chapter 1

Introduction

1.1 Purpose of this Paper

Unmanned Aerial Vehicles (UAVs), commonly referred to as drones, are aircraft capable of sustained flight without a pilot on board. In recent years UAVs have transformed numerous sectors — from precision irrigation and cargo delivery to aerial reconnaissance, commercial services, and tactical defense operations [1],[2]. Current UAV designs tend to be purpose-built: some prioritize speed, others maximize payload capacity, some are ultra-small (nano-UAVs), and others are engineered for extended long-range missions [3]. Few platforms, however, provide a flexible solution that effectively addresses both short-range and long-range mission requirements. This paper presents a novel system and conceptual approach aimed at bridging that divide by delivering adaptable capabilities for both mission profiles.

This paper presents the Kak–Kokil UAV concept: a complementary pair of unmanned aerial systems designed to combine long-endurance surveillance with agile, short-range tactical capability [4],[5]. Kokil is a low-cost, short-range UAV developed for tactical reconnaissance in confined or sensitive environments where rapid response, maneuverability, and targeting accuracy are essential [6]. Kak is a hybrid, long-endurance platform tailored for extended missions and sustained aerial surveillance [7],[11]. Together, these vehicles form an integrated system in which Kak functions as a deployment and support platform for Kokil, enabling mission profiles that neither platform could achieve alone.

The primary focus of this work is the design and construction of Kokil. We provide detailed schematics, component selection rationale, and a build-from-scratch methodology covering mechanical design, propulsion, avionics, and flight-control integration [8],[9]. The paper also discusses Kak's architecture and its role as a deployment and communication relay for Kokil. [10],[12] Our principal research objective is to investigate the engineering challenges that arise when constructing these two UAV classes — specifically, how to integrate propulsion systems with flight-control electronics and payload handling subsystems — and to propose practical solutions that enhance modularity, reduce cost, and broaden applicability for both civilian and defense use cases (e.g., surveillance, reconnaissance, and rapid tactical deployment) [13].

Finally, we propose and evaluate a dual-drone operational concept that integrates long-range and short-range UAVs into a single, coordinated system, and we outline future work required to validate the concept in field trials.

1.2 Contextual Background

The introduction of UAVs has changed modern warfare in a big way, making surveillance and precision strikes much better [1]. Drones, like the Turkish Bayraktar TB2, are very useful in modern military operations since they give real-time intelligence and make targeted strikes with little risk to human life [5]. The present crisis between Russia and Ukraine shows how much more military operations are relying on UAV technology [6]. UAVs are now quite important for modern warfare.

They have changed the way we fight and defend ourselves in a big way. As UAV technology keeps becoming better, it will change how the military plans and uses them in different situations [7].

1.3 Motivation

The military, business, and humanitarian sectors have all been greatly affected by how quickly UAV technologies have improved [2]. The Kak and Kokil drones were made to meet the growing need for drones that can do certain tasks [4]. Kak is better for long-range reconnaissance and quick deployment, while Kokil is better for giving a flexible way to acquire intelligence and watch over sensitive or small areas [6]. Both UAVs show that there is a growing need for flexible and dependable drone systems that can handle a variety of mission types [9],[12].

1.4 Problem Statement

Even though UAV technology has come a long way, there is still a need for UAVs that can easily convert between different mission needs [3]. Most UAVs are built to either last a long time or be very agile, but they don't often do both well at the same time [6]. The problem, therefore, lies in creating UAVs that balance performance across diverse mission profiles, such as long-range surveillance, quick tactical deployment, and operation in complex environments [4],[8],[13].

1.5 Objectives

The primary objectives of this paper are:

- i To design and develop two types of UAVs—Kak, a hybrid propulsion long-range drone, and Kokil, a short-range quadcopter optimized for reconnaissance [3],[4].
- ii To differentiate the differences of types of propulsion systems, like jet fuel for Kak and electric motors for Kokil, may be used in UAV designs to fit the needs of a certain mission [18].
- iii To analyze the engineering challenges faced during the development process, such as payload integration, flight stability, and power management [7],[12].
- iv To investigate how these UAVs might be used in both military and civilian settings, with an emphasis on improving tactical and strategic operations [5],[8],[13].

1.6 Limitations

This study examines the design and deployment of kokil and provides a brief overview of the kak concept.

1.7 Report Organization

This report is organized as follows:

- i Chapter 1: The Past of UAVs - Provides a historical overview of UAV development, from early innovations to modern-day applications in military and civilian sectors.
- ii Chapter 2: The Physics of UAVs & Newton's Laws - Discusses the fundamental physics principles governing UAV flight, including Newton's laws and the control systems used to stabilize and maneuver UAVs.

iii Chapter 3: Components of UAVs - Describes the key components that make up the UAV systems, including propulsion, flight control systems, and sensors.
iv Chapter 4: Kokil - Focuses on the design and functionalities of the Kokil quadcopter, emphasizing its application in reconnaissance and surveillance missions.
v Chapter 5: Engineering Difficulties and Remedies - Outlines the technical challenges encountered during the development process and the solutions implemented to address them.
vi Chapter 6: Kak - A Hybrid Propulsion UAV for All Types of Missions - Details the design and performance of the Kak UAV, highlighting its dual propulsion system and adaptability to various mission types.
vii Chapter 7: Conclusion and Future Work - Summarizes the findings of the paper and provides recommendations for future research and development in UAV technology.

Chapter 2

Background

2.1 Early Developments:

The first actual pilotless flying machine from the United States was the Kettering Bug during World War I. This is the genesis of UAVs [3]. It was anchored well away from anything it might attack, but its very existence opened the evolutionary door to future UAVs. The Radio plane OQ-2, built by actor Reginald Denny during World War II, represented a huge leap in UAV tech. The OQ-2 became the first mass-produced drone. It was mainly for use as a target in training anti-aircraft gunners [5]. Nazi Germany's V-1 flying bomb also demonstrated how UAVs might be weaponized [4].

2.2 Cold War Era:

The development of UAV technology was fairly rapid during the Cold War. The US and Russia have developed reconnaissance drones separately, as have most countries [5]. These UAVs we-re used to collect data over hostile locations, and they then evolved into modern drone surveillance technology [7].

2.3 Modern Military Use:

In the 1990s, UAVs went from being a fun thing to use to a serious tool for the military [6]. The MQ-1 Predator was a step in the right direction because it could do reconnaissance and carry munitions that were guided by GPS [5]. There were a lot more military drones in the 21st century, such the MQ-9 Reaper, which is used a lot for surveillance, reconnaissance, and targeted strikes. The ongoing war between Russia and Ukraine has shown how important UAVs are in modern warfare. They are now the most common platforms for surveillance and reconnaissance operations. Drones like the Bayraktar TB2 have changed the way power works on the battlefield. [7].

2.4 Civilian and Commercial Use:

Drones are not just for the military; they have become one of the most important tools for everyday people. Drones are utilized for a lot of different activities these days, like farming, making movies, and helping people after a disaster. They are very valuable in many jobs because they can get real-time data from places that seem impossible to reach [8],[10].

2.5 Shahed Kamikaze Drone

The Shahed drones are cheap, single-use weapons that can stay in the air for 1,000 to 2,000 kilometers. They can carry 30 to 50 kg of cargo for accurate hits [18]. They are easy targets for electronic warfare because they employ GLONASS navigation and don't have advanced stealth features [6]. They can be found by modern air defense systems.

Inspiration for Kak UAV:

The design of the Shahed drones affected the development of the Kak UAV in the following ways: Hybrid Propulsion: Kak's design may be used again, but Shahed's design can only be utilized once. This makes Kak's design more efficient [4],[18].

Stealth Technology: Kak employs an organic leather coating to assist it dodge radar, which overcomes the stealth concerns with Shahed drones [12]. Autonomous Navigation: Kak employs advanced autonomy and resistance to electronic countermeasures to get around Shahed's reliance on basic navigation technologies [8],[13].

Drone Physics:

2.6 Application of Newton's Laws to UAVs

Newton's **Laws of Motion** form the fundamental physics governing the flight dynamics of both **Kak** and **Kokil** [3],[5]. Understanding and applying these laws is critical to the design of both UAVs, as they affect everything from propulsion to flight stability.

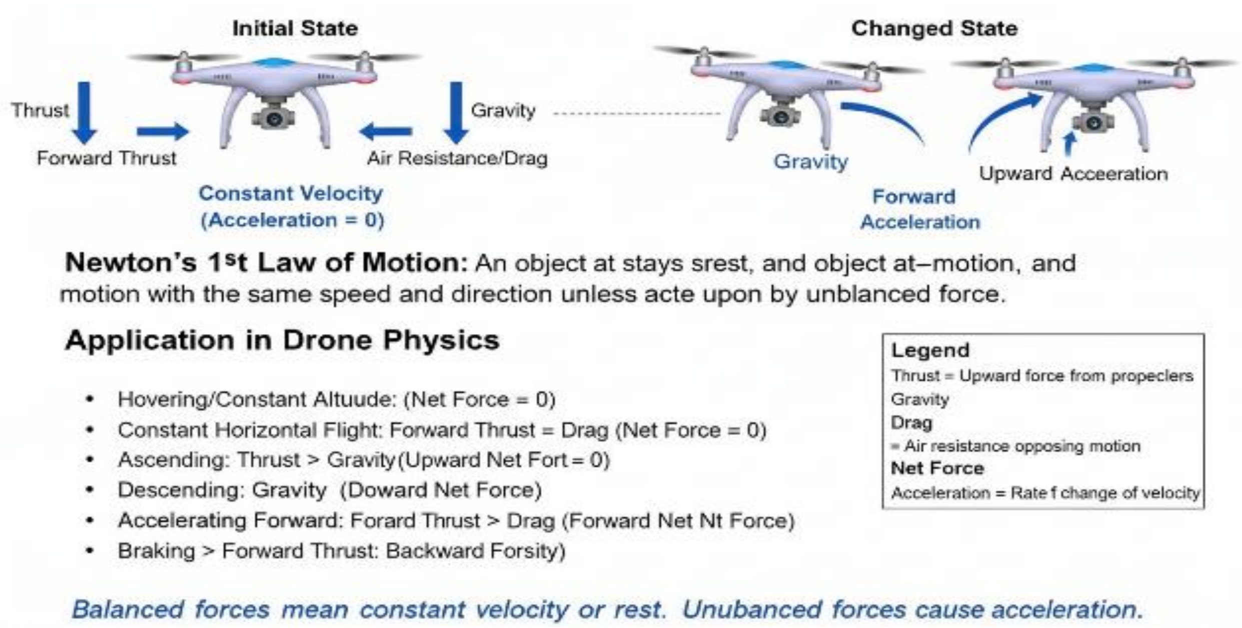

Figure No: 2.1 (Newton's Laws and Their Application in UAV Flight)

2.6.1 First Law of Inertia ($F = G (m_1 m_2 / r^2$):

When the thrust from its propellers is equal to its weight, a drone stays in the air. Once flying, it will continue to fly if left alone (disregarding air resistance, gravity, and losing motor power). This is why a drone has to be constantly powered to stay in the air [7].

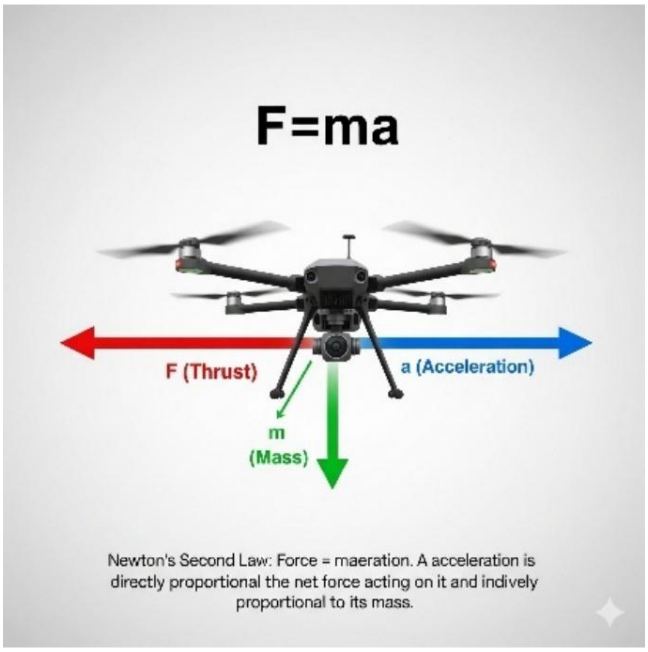

Figure No: 2.2 (Illustration of First Law of Inertia Applied to UAV Flight)

2.6.2 Second Law (F = ma):

The motors' force and the drone's bulk both affect how fast it can go. Lighter drones like Kokil need less force to get off the ground and can move around and stay in the air longer than heavier drones [6],[12].

2.6.3 Third Law (Action–Reaction):

The propellers on a drone push air down, which makes it lift. Newton's third rule of motion, "Action-Reaction," says that when the propellers push air down with a specific force (action), the air pushes back with an equal and opposite force (reaction). This elevates the drone. But the propellers also create torque when they spin, which can make the drone spin out of control. To fix this, drones have several rotors that rotate in different directions. This creates equal and opposite torques, which helps keep the drone stable and under control while it's flying [8],[13].

2.7 Coordinate Systems and Motions in UAVs

To control and fly in the sky properly, UAVs are dependent on a coordinate system, where an attitude and a rotation movement are described. These axes and rotations are required due to stability, and flight control.

X-axis: X-axis is left/right or west/east. Flight The drone moves up and down along this axis as it flies. As the drone flies on this axis, it flies in a forward and backward manner [6].
Y-axis: Y-axis move either in forward/back or north/south. Move the drone sideways by translating on the Y [7].

Z-axis: Z-axis is an up/down direction. This axis regulates the vertical movement determining the upward and downward movement [8].

2.8 Rotational Movements (Euler Angles)

UAVs rotate about three axes for stability and maneuverability. These rotations are crucial in attitude control of the drone; they influence the orientation and the flight direction of the drone [12]:

Roll: Roll represents a rotation of the UAV around the Y-axis. When the drone pitches forward or backward, it is said to be pitching. This action influences the lateral tilt and also assists the drone to stabilize in the horizontal level [6].

Pitch: Pitch is about the X-axis. When the UAV pitches (leans forward or backward). This is how the drone moves horizontally (forward/backward) [3],[5].

Yaw: Yaw rotation is around the Z-axis. If the UAV rotates from left to right or vice versa without altering its pitch or roll, it is yawing. This motion controls the direction in which the drone flies in the horizontal plane, allowing it to steer without tilting [7].

By regulating these axes and their rotational movement, UAVs can fly steadily, maneuver, and respond promptly to instructions. Gyroscopes and accelerometers are one of the types of quadcopter flight controller sensors that will be included, maintaining its direction through the air and communicating what is happening within the drone to adapt to its environment, whether it be windier skies or a new location being flown in

Basic schematic of a Quadcopter drone:

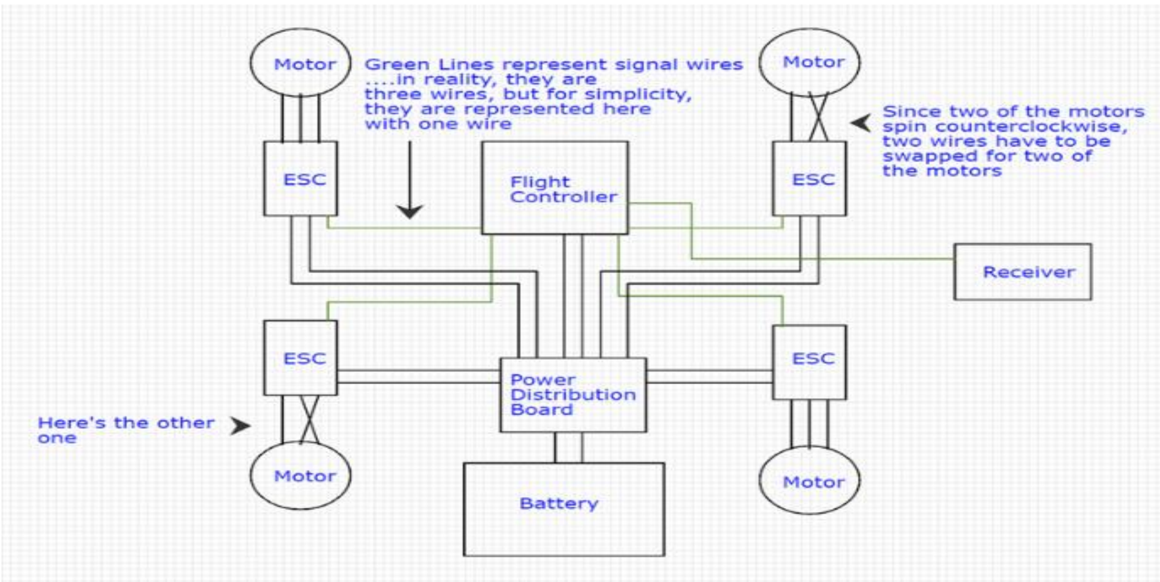

Figure No: 2.3 (Basic Quadcopter Schematic)

2.9 Black Hornet Nano Drone

Technical Features and Ideas for the Kak UAV
The Black Hornet Nano is a very small micro UAV made for tactical reconnaissance. It weighs only 33 grams and can fly for up to 25 minutes while monitoring in real time from a distance of 2 km [14]. It has high-definition cameras that let it do clandestine operations in cities and other crowded areas. Because of its compact size and stealthy design, it is very impossible to find, making it perfect for military and intelligence use [7].


Figure No: 2.4 (Black Hornet drone)

Inspiration for Kokil UAV

The design of the Black Hornet Nano influenced the development of the Kak UAV in the following ways:

i. Compact Design: Kak incorporates a modular and lightweight structure, optimizing maneuverability in constrained environments, inspired by the Black Hornet's small form factor [14].
ii. Stealth Features: Kak enhances its radar evasion with an organic leather coating, building on the Black Hornet's stealth capabilities [12].
iii. Tactical Application: Like the Black Hornet, Kak is designed to perform covert operations and surveillance but on a larger scale, with the added benefit of multi-role functionality [13].

2.10 Literature Review:

a) Overview: A comprehensive literature review on UAV technology with attention on hybrid propulsion, flight control systems and tactical reconnaissance.

b) Key Areas to Cover:
i UAV propulsion systems (e.g. hybrid, electric motors).
ii Flight control and stability.
iii Design of small UAVs such as Kokil.
iv Military and civilian applications of UAVs (e.g. environmental monitoring, surveillance)

Example Table (2.1) for Literature Review:

Author(s)	Year	Title	Methodology	Key Findings
D.A.khan [1]	2017	UAV Propulsion Systems	Analytical study	Found hybrid propulsion systems offer increased efficiency for long-range missions.
Smith and Lee[4]	2019	Flight Stability in Tactical UAVs	Experimental analysis	Highlighted the importance of modular design for compact UAVs.
Zhang and Lee [15]	2021	UAV Applications in Military and Civil Sectors	Case study and simulations	Identified growing use of UAVs in both military surveillance and disaster response.

2.11 Gap Analysis

Overview: Discuss the gaps in current UAV systems that the **Kak** and **Kokil** UAVs aim to address. This will include:

i Lack of **dual-role systems** (combining long-range and tactical capabilities).

ii Limited **modular designs** for mission adaptability (e.g., engine swapping, payload flexibility).

iii The need for **cost-effective UAV systems** that can be used for both military and civilian applications.

Sample Table (2.2) for Gap Analysis:

Feature	Current UAV Systems	Proposed Kak & Kokil System
Engine Propulsion	Limited to jet or electric motors	**Hybrid system** for flexibility (jet + electric).
Payload Flexibility	Fixed payloads for specific missions	**Modular payload** system for a variety of mission types.
Mission Adaptability	Single-role applications (e.g., surveillance or tactical)	Dual-role system offering **long-range surveillance** and **short-range tactical reconnaissance**.
Cost-Effectiveness	High operational costs for military-grade UAVs	**Cost-effective** design suitable for **mass deployment**.

2.12 Similar Applications

Similar Applications
a) Other UAV-like Systems: Talk about other UAVs whose applications or design philosophy are similar to one, e.g.:

i Shahed-136: This is a long-range UAV with a single use in the military. Inspired Kak's reusability.

ii Black Hornet Nano: A small UAV used as a tactical reconnaissance, which helped Kokil to shape his design around agility and small size.

b) Overview of related Usages:
Shahed-136 was the prototype behind Kaks hybrid propulsion and reusability.
The presence of Black Hornet Nano informed the compact design, stealth and rapid deployment capability of Kokil.

Summary:
Chapter 2 gives a background of UAV technology in detail, discussing the major literature and gaps that Kak and Kokil systems will fill. It equally makes comparisons of the proposed UAV systems with other UAVs and shows their contribution differences to the UAV research and application.

Chapter 3

Research Methodology

This chapter describes how the dual UAV system was designed, built, and tested. The system consists of Kak, a long-range hybrid propulsion UAV, and Kokil, a small tactical reconnaissance UAV. The process includes coming up with ideas, designing the system, and dealing with technical problems. It shows how the systems are developed and tested to achieve the study goals.

3.1 Overview

This research aims to create and build a dual UAV system that combines the best features of Kak and Kokil. But our main focous on A proper development of Kokil That why we providing resouses for design and proper way to make the kokil

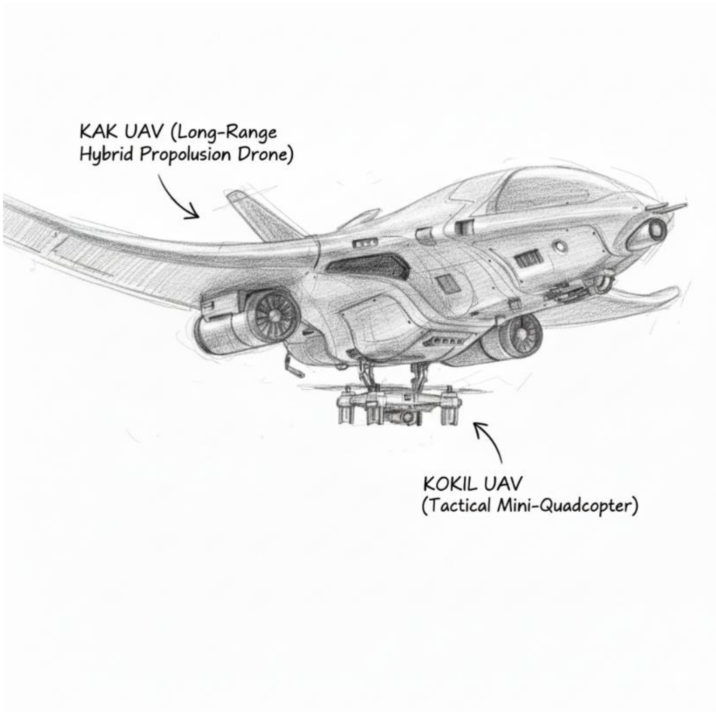

Figure No: 3.1 (KAK & KOKIL)

3.2 System Design and Suggested Method

The system design is based on the combination of two different UAVs, Kak and Kokil. Each has its own mission duty, but they work together to make a flexible and adaptive UAV system [4],[18].

Kokil UAV: Kokil is a small quadcopter that is best for short-range tactical reconnaissance. It is made to be set up quickly in small, crowded areas or tight locations. Kokil has a multilayered nano custom-made PCB for the flight control system made with MPU6050 additionally some 805 chips to power it up and for the brain of the drone we picked ESP Xiao and for the communication with the main mother drone we relied on ESP Xiao signal antenna for the camp feed we chose the native nano cam it has a built-in 4.5 GZ video transmuting module with a 10 mega pixel camera Csensors to make sure it stays stable and under control.

The twin UAV system lets Kak move Kokil over long distances and then drop Kokil off in the target region for surveillance or reconnaissance. This method makes use of Kak's strength and Kokil's speed, making it a flexible option for both military and civilian uses.

For the deployment mechanism, we chose a servo-powered payload release mechanism that can.The dual UAV system allows **Kak** to transport **Kokil** over long distances and then deploy Kokil in the target area for surveillance or reconnaissance. This approach takes advantage of Kak's **endurance** and Kokil's **agility**, making it a flexible solution for a range of **military and civilian applications** [7],[12].

Kak UAV: Kak has a hybrid propulsion system that is powered by NVIDIA Jetson Neno, That offer us to withc the engine for the visitile tasks in quieter, stealthier operations in sensitive areas. Its main key feature is to carry the kokill on the desired area (long range) and deploy it from a high altitude [3],[4].

3.3 Functional and Non-Functional Requirements

To ensure the success of the UAV system, both Kak and Kokil were designed to meet specific functional and non-functional requirements.

a) **Functional Requirements:**

  i. **Kokil:**

  Kokil designed is high-speed and is deployed in situations involving tactics.

  maneuver and stability, to enable tight or narrow space control. It is most suitable in complex environments because it is mainly used to collect vital information in regions that are normally difficult to reach [7],[12],[14].

  ii. **Kak:**

  Able to fly long-range reconnaissance, and can alternate jet engine with electric motor, according to the mission imperatives. It also possesses modular payload system and this enables flexibility in executing tasks [3],[4],[18].

b) **Non-Functional Requirements:**

  i. **Kokil:**

  Lightweight and stealthy, with an emphasis on extended flight time using LiPo batteries .it has a low flight time due to 1500mAh 3.7 battery. It can power the drone for approximately 15–18 minutes, but if flown at higher speeds, the flight time is reduced to only 8–10 minutes. It needs to be strong enough to handle harsh weather and still be able to move quickly during tactical deployments.
  it also required a skilled pilot to operate it [6],[7],[14].

  ii. **Kak-Concept:**

  Kak was mostly made to transport and deploy the Kokil, which is like a mother drone. But because of its variety, we can use it for a lot of different things. It is both cost-effective and useful for both military and civilian use. Its design lets you change engines for different tasks. Also, the UAV is made to use as little energy as possible, carefully controlling how much fuel it uses on long flights [8],[12],[18].

3.4 Data Flow Diagram (DFD)

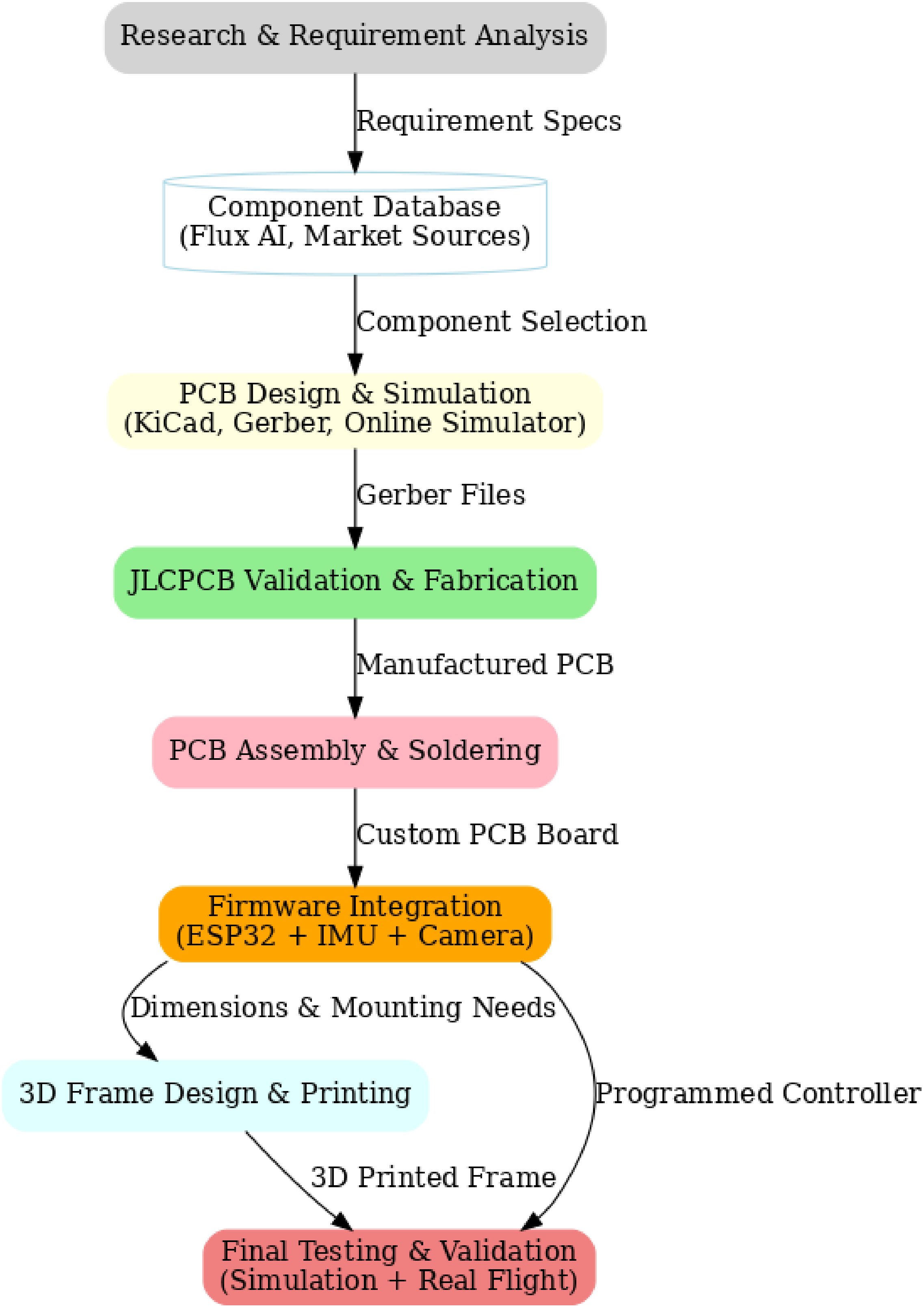

Figure No: 3.2 (Data Flow Diagram (DFD) for UAV)

To understand how data flows between the different systems in the UAVs, we've created a **Data Flow Diagram (DFD)**. The DFD illustrates how the **flight control system**, **sensor data**, and **payload systems** interact with each other within both UAVs [8],[12].

Level 0: Context Diagram
At this level, you show the system as a single process with inputs and outputs, without detailing internal processes [18].

System: PCB Design and Testing System
Input: Research & Requirement Analysis, Component Database, Firmware (ESP32, IMU, Camera)
Output: Custom PCB, Programmed Controller, Tested & Validated Product

Level 1: High-Level Process
This level breaks the single process into main sub-processes with inputs and outputs.
Research & Requirement Analysis
Input: Requirement Specs
Output: Component Database, Requirement Specifications
Component Selection and PCB Design
Input: Component Database
Output: Gerber Files, PCB Design
PCB Manufacturing & Assembly
Input: Gerber Files
Output: Manufactured PCB, Assembled & Soldered PCB Board
Firmware Integration
Input: ESP32, IMU, Camera
Output: Programmed Controller, Firmware Integrated System
3D Frame Design & Printing
Input: Dimensions & Mounting Needs
Output: 3D Printed Frame
Final Testing & Validation
Input: Assembled PCB, 3D Printed Frame, Programmed Controller
Output: Validated Product, Simulation + Real Flight Data

Level 2: Detailed Processes
This level would break down the sub-processes even further, showing the internal steps for each main process.
For example, for the PCB Manufacturing & Assembly sub-process:
PCB Design & Simulation
Input: Component Selection
Output: KiCad Design Files, Gerber Files
Fabrication and Validation
Input: Gerber Files
Output: Validated and Fabricated PCB from JLCPCB
PCB Assembly & Soldering
Input: Manufactured PCB
Output: Assembled PCB

Similarly, each high-level process like Firmware Integration and 3D Frame Design can be broken into smaller steps for clarity. This helps visualize every internal detail, including every input, output, and transformation in the system.

3.5 Project Plan

Our project was separated into well-planned stages to successfully design, develop and assesses Kak and Kokil UAV system. All the stages were to be arranged to enable gradual progress, enable progressive enhancements and reduce risks. The plan was in sync with a semester plan which started with the initial design phase up to testing and documentation.

Phase 1 Research and Requirement Analysis (Weeks 1216)
At this point, we made a detailed study of UAV technologies, including propulsion systems, flight controllers, and deployment systems. We determined both functional and non-functional requirements of both Kak and Kokil. Meanwhile, we compared existing solutions (e.g. Shahed and black hornet UAVs) to get a clearer picture of design shortcomings.

Phase 2- Hardware and PCB Development (Weeks 16-24)
The focus of this phase was the development of the custom flight controller PCB of Kokil. We chose ESP32-S3, MPU6050 and MOSFETs as the main elements. The schematic was drawn in KiCad with prototype fabricated thereafter. The hybrid propulsion system and modular housing of Kak were researched parallel to each other.

Phase 3 System Design and Prototyping (weeks 24-32)
We moved on to schematics to hardware integration. The body of Kokil was 3D printed and modeled so that it had a light weight but strong frame. The PCB included power systems, sensors and motors. They were early coded with stabilization and free-fall detection. In the case of Kak, we optimised the concept of modular design and mapped deployment mechanisms.

Phase 4 Testing and Iteration (Weeks 32 42)
The stability and response time of Kokil was tested by means of flight simulations and lab-scale experiments. Any fault in the PCB or body frame was determined and rectified by the means of making improvements. Another study that we conducted on Kak was with respect to endurance in simulation with the aim of engine-swapping.

Phase 5 Final Integration and Evaluation (Weeks 4248)
The third step united all the sub-systems. Kak was tested to deploy Kokil during the process of a mission, whereas Kokil was tested to perform agility, stability and tactical reconnaissance. We quantified endurance and payload flexibility, and system feasibility. This stag was during which the final report, documentation and presentation were prepare

Table No: 3.1 Task Allocation

This table depicts the timeline of the principal activities in each period of the project, from week 12 to week 48.

Tasks	Weeks																	
	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
Flight Controller PCB Innovation for Kokil																			
Design Custom Controller PCB & chips selection																			
Finalizing and testing the PCB and environmental codes																			
Custom 3D Body design for Kolli																			
Research on Kak's UAVs inter-system																			

3.6 Summary

This section provided a methodology for the development of the Kak and Kokil UAV system, focusing on the engineering specifications; data generation; and the use of Newton 's Laws in the design of the UAV systems. This method for developing the UAV system, which in stitutionalizes the project process andconfronts the engineering challenges step by step, makes the completion of the one successful.

Chapter 4

Implementation and Results

The primary reason for developing a custom PCB flight controller for Kokil is the lack of commercially available nano-sized drones in the market. By designing a tailored PCB, we enable greater flexibility, compact integration, and open up numerous possibilities for innovation and future enhancements.

4.1 Major Components for Kokil

i **Frame/Body:** The frame of a UAV can be made of robust, yet light weight, material, such as carbon fiber or aluminum. This balance is essential to achieving optimal performance and efficiency, especially with a small payload such as Kokil [6].

ii **Propulsion System**: The Unmanned Aerial Vehicles (UAVs) produces lift using brushless DC(19000kv) 4*15 motors and 1nm "D" type propellers. These and the ESCs allow to accurately adjust the drone's flight pattern. The control unit is the main element to determine the thrust-to-weight ratio of this drone, and will consequently determine the drone's stability and flight time [5].

iii **Flight Controller:** we are using a custom made multi-layer PCB pairing it with esp XIAO The flight controller is the brain of the drone, using sensors such as gyroscopes, accelerometers and barometers to keep the drone stable and translate the pilot's inputs. XIAO ESP32-S3 flight controller for Kokil It plays nicely with the MPU6050 IMU for great control over your craft [12].

iv **Battery/Power System:** 3.7v Drones are powered by high-density lithium-polymer \(Li-Po\) batteries. These batteries also have one of the best weight-to-power ratios among all batteries [13].

v **Controller and Communication System:** A communication system that transmits a backhaul with remote control sews and the collected data from the UAV to the operator. The communication usually consists of radio frequency (RF) link or Wi-Fi system, considering the range and mission of the UAV [7].

vi **Payload:** They even can be loaded with cameras and thermal sensors into weaponry for military purposes. The weight a Drone can carry varies based on the size and type of propulsion (motor) used [1].

Table 4.1: Core Kokil Drone Component Costs

Component	Qty	Real Price (USD)	Purpose
ESP32-S3 Microcontroller	1	$17	Main flight controller
MPU6050 Gyroscope/Accelerometer	1	$4	Orientation and stabilization
SI2300 N-MOSFETs	4	$1 (bulk)	Motor power switching
1N4148 Switching Diodes	4	$0.20 (bulk)	Circuit protection
Brushless/Coreless Motors	4	$32 (~$8 each)	Propulsion
Propellers	4	$4 (~$1 each)	Lift generation
LiPo Battery (1S/2S, 500–800mAh)	1	$10	Power source
JST Connector + Wires	–	$4	Power connection
3D Printed Frame (7g filament)	–	$3	Structure

Core Drone Total = ~$45–50

This confirms that a **single Kokil drone unit** can be manufactured at very low cost, making it highly scalable for mass deployment.

However, the **overall project cost** must also include tools, accessories, and logistical expenses needed during development and testing. These costs do not directly belong to the per-drone hardware, but they represent the **true project budget** when building and testing the prototype.
However, the **overall project cost** must also include tools, accessories, and logistical expenses needed during development and testing. These costs do not directly belong to the per-drone hardware, but they represent the **true project budget** when building and testing the prototype [7].

Table 4.2: Accessory and Overhead Costs

Accessory / Expense	Qty	Price Range (USD)	Purpose
FPV Camera Module	1	\$40 – \$70	Video transmission
VR / FPV Goggles	1	\$40 – \$60	First-person view control
RC Controller & Receiver	1	\$20 – \$30	Manual drone control
Soldering Station	1	\$20 – \$30	Assembly & testing
PCB Fabrication & Assembly	–	\$20 – \$50	PCB prototyping
3D Printing (frame iterations)	–	\$10 – \$20	Prototyping costs
Shipping / Transport	–	\$15 – \$30	Delivery charges
Import Duties / Taxes	–	\$20 – \$40	Customs / VAT
Miscellaneous (cables, spares)	–	\$10 – \$20	Extra components

Accessory/Overhead Total = ~\$200 ± \$50

Final Cost Summary:

- **Core Kokil Drone Build Cost:** ~\$40–50 per unit
- **Accessories & Overhead (project-level):** ~\$200 ± \$50
- **Total Development Budget: ~\$250–300**

Total Estimated Cost of Components: \$356.57. (approx.)

(**Note we've bought the components in bulk, that's why it costs too much, but if we consider for per unit cost, it will be approximately 40-50$**) [7]

Stamatis of Custom MPU 6050 flight controllers:

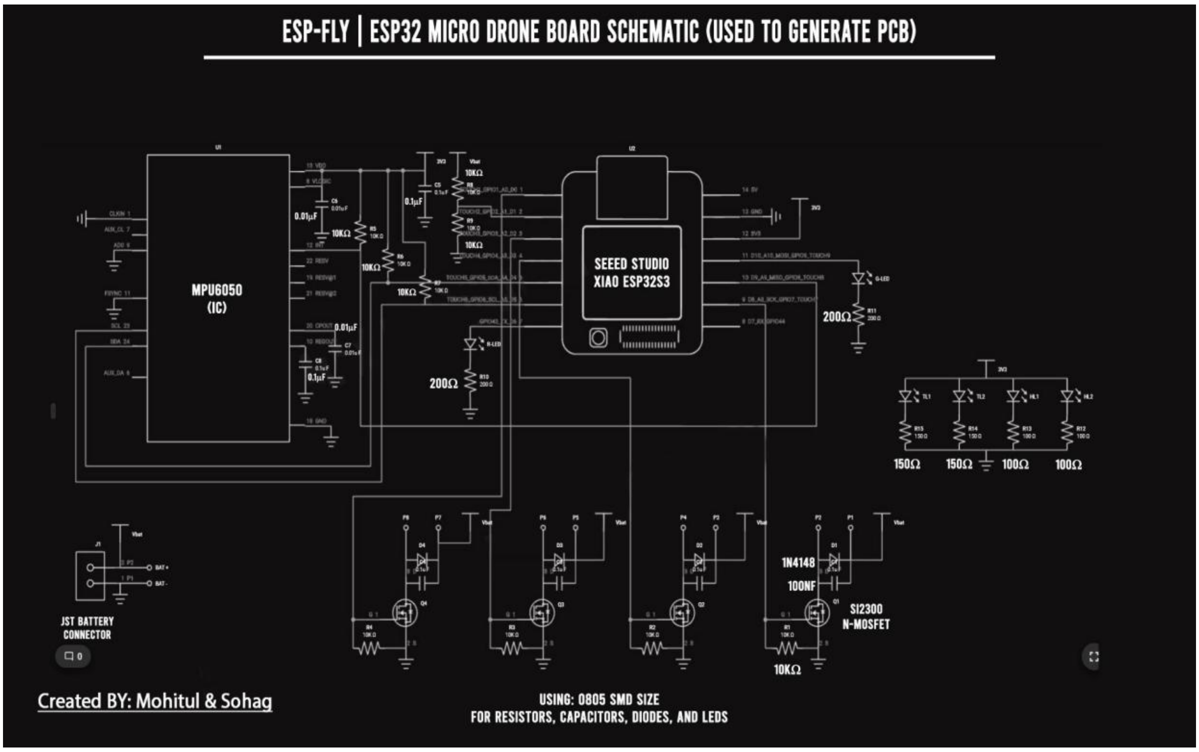

Figure No: 4.1 (Custom Flight Controller Schematic for Kokil UAV)

KI Cad design file for Gruber File:

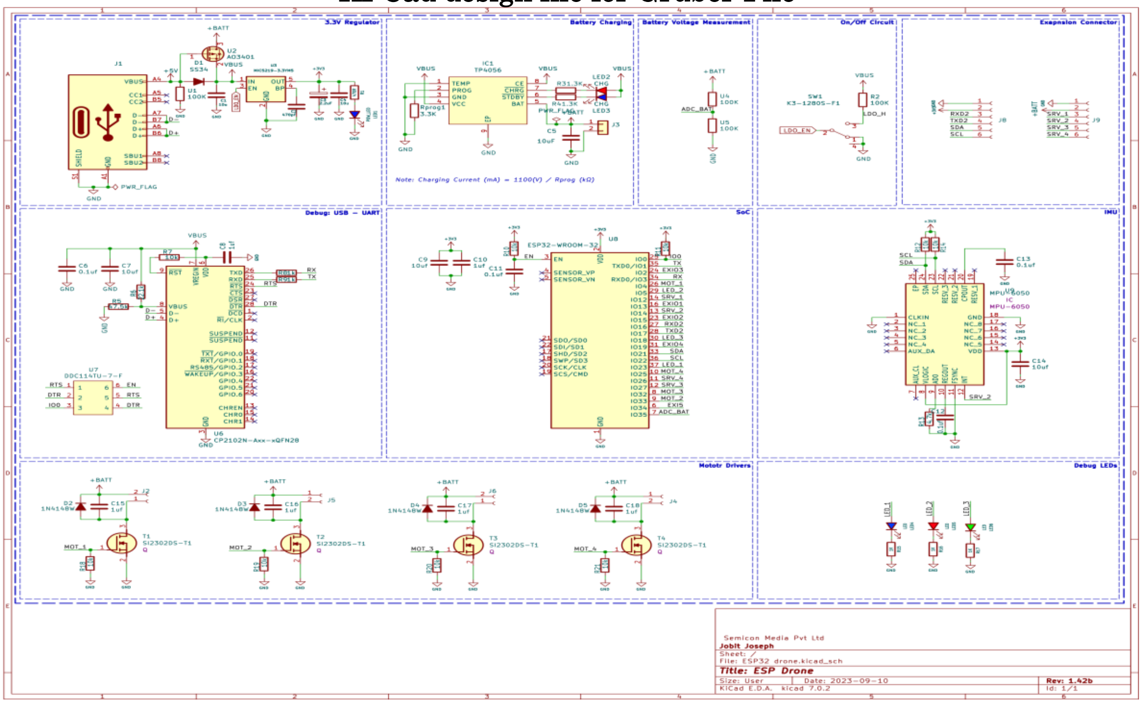

Figure No: 4.2 (KiCad Design File for Kokil's PCB)

PCB 3D Gerber View:

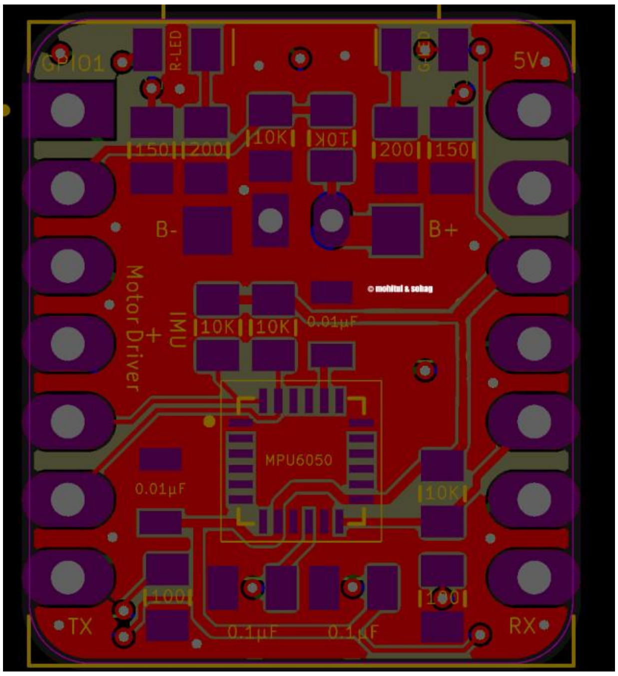

Figure No: 4.3 (3D Gerber View of Kokil's PCB) Top View
(**The top part is for IC handling.)

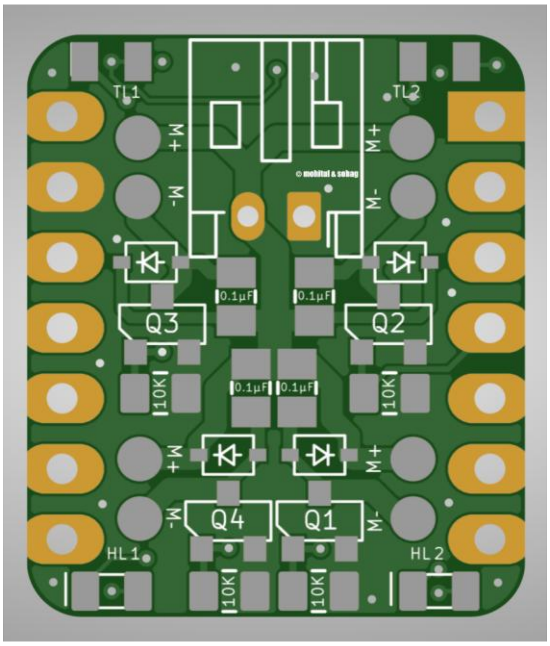

Figure No: 4.4 (3D Gerber View of Kokil's PCB) Bottom View
(**Bottom part is for motor drivers)

Explanation of the Schematic

4.2. ESP32-CAM (XIAO ESP32-S3 Module)

i The heart of the system is the ESP32-CAM, a tiny and affordable MCU with built-in camera and wireless connectivity. It has more RAM and resolution compared to the standard ESP32 (which is missing Bluetooth and Discovery).
ii **Pinout**: The ESP32 module is wired to required sensors and actuators in the schematic.
iii **GPIO Pins**: Allocated for touch sensors, LEDs, and other peripherals like motors and communication systems.
iv **Power Usage**: Experience safer power usage with detailed GPIO instructions [3],[12].

.

4.3. MPU6050 Sensor (Accelerometer and Gyroscope)

i The MPU6050 senses orientation and acceleration information to maintain drone balance in the air. It is crucial for attitude control.
ii **Connection**: Connected to the ESP32 via the I2C bus (SDA and SCL pins).
iii **Function**: Senses fall and orientation, informing the arm and spin-up mechanism when the drone is dropped [7],[12].

4.4. Battery Power and JST Connector

i The JST connector (P1 and P2) connects the LiPo battery to power the device, including the ESP32-CAM and motors.
ii **Voltage Protection**: Units like D1 (1N4148 Diode) protect against over-voltage or reverse voltage, ensuring safe circuit operation.
iii **Power Distribution**: The power is distributed to the ESP32, MPU6050, and other components through resistors and transistors [3].

4.5. MOSFETs and Motor Control

i MOSFETs (e.g., SI2300 N-MOSFET) are used to distribute power to the brushless motors responsible for thrust and flight control.
ii **Connection**: The MOSFETs control power to the motors, with signals from the ESP32.
iii **Objective**: When freefall is detected, MOSFETs manage motor startup and throttle to ensure rapid spin-up upon launch [18].

4.6. Resistors, Capacitors, and Diodes

i **Resistors** (e.g., 150Ω, 100Ω) and **capacitors** (e.g., 0.1µF) are used for signal conditioning, voltage regulation, and biasing active components.
ii **Diodes** like the 1N4148 are used to protect the circuit from reverse voltage input, preventing damage if components are reversed [10].

4.7. LEDs

LED Indicators: Connected to GPIO pins on the ESP32-CAM for visual feedback on the drone's status.
i **Green LED**: Indicates power or system status.
ii **Red LED**: Signals a problem, such as low battery or failure to stabilize [5].

4.8 Adding another Schematic Portion and Comment

Now that we've reviewed the current schematic, lets discuss adding a new segment for expansion.

Proposed New Schematic Segment

- i More sensors, more flexibility: Add more sensors such as Barometer, Proximity (e.g. ToF) or even GPS for more precise control and added stability.
- ii Connect to flight controller: Demonstrate how the new sensors connect to ESP32-CAM and how there would utilize pre-existing systems such as MPU6050.
- iii Elevator – barometer for altitude hold and flight stabilization.
- iv ToF sensor – detect the close objects and avoid object collision, with the ability to fly in any direction you want.
- v Motor/ESC operation: Explain what component are being employed by the ESCs to the motor drivers threw the MOSFETs and how it outputs the motor spin up and thrust changes [8].

4.9 Additional Sensor Inputs:

- i The additional schematic part will demonstrate where barometers or proximity sensors can be added to the ESP32-CAM with I2C (or UART) communication. These sensors help improve the drone's ability to hover and maintain stability with or without GPS, based on altitude or distance hold.
- ii Incorporating Additional Logic:
- iii Write some more code that leverages the new sensors for making the drome more steady. For instance, the barometer can control throttle to ensure a target altitude is achieved, and/or sensor ToF can trigger warning when a barrier is too close when a flying process.
- iv Power Management:
- v If they should need to add new components such a barometer, the power must be handled efficiently to leverage the battery life and avoid overpowering the setup. The circuits should also include power regulators for both 3.3V and 5V systems [8].

This represents the actual size of Flight Controller:

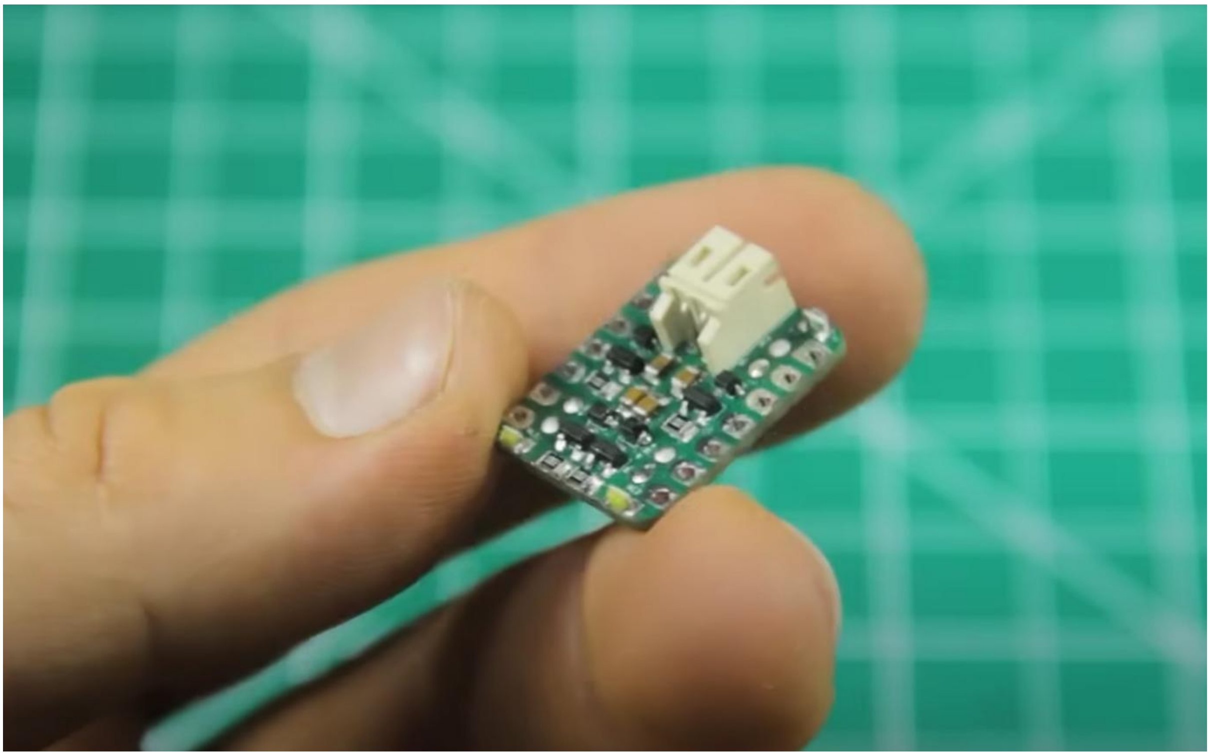

Figure No: 4.5 (Size of Flight Controller)

****This represents the actual size of the PCB:**

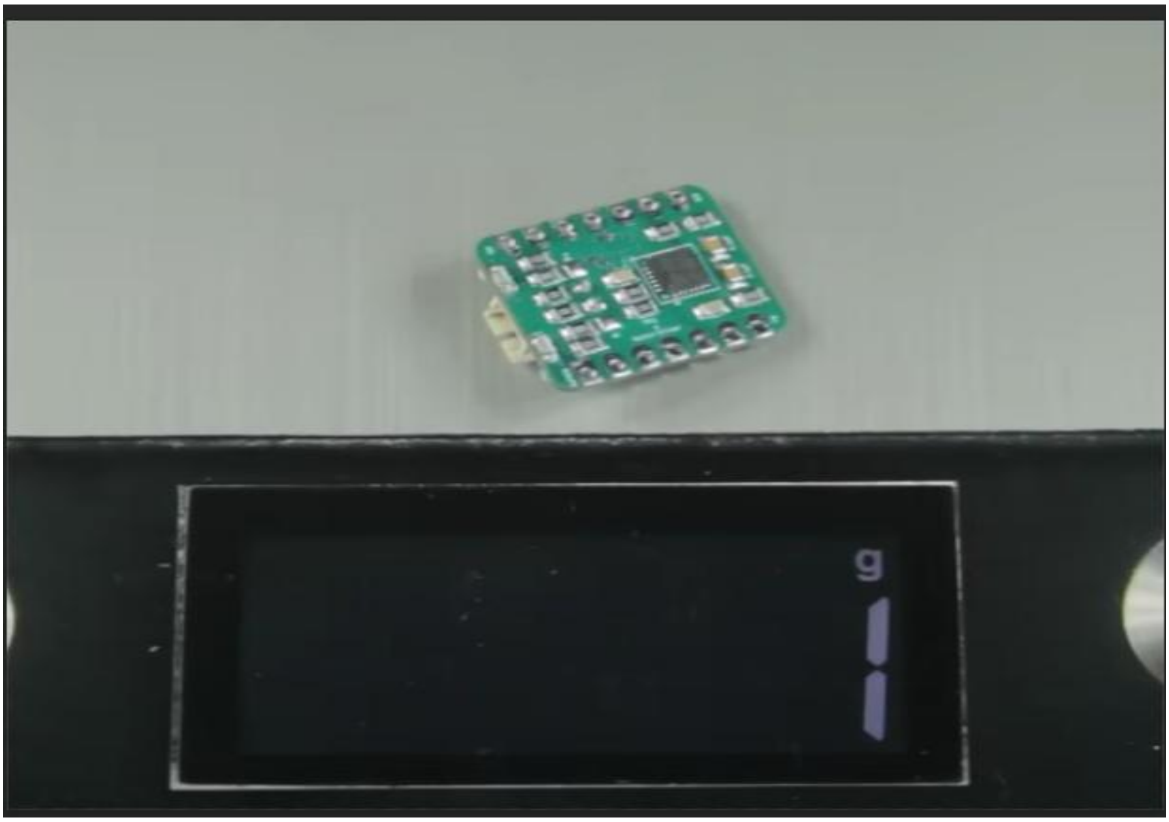

Figure No: 4.6 (Weight of flight controller)

Table 4.3: Drone Flight Controller Comparison Box

Feature	ESP32-S3 + MPU6050 Board (This Schematic)	Typical Commercial Flight Controller (Pixhawk, BetaFPV, etc.)
Main Processor	Seeed Studio XIAO ESP32-S3 (dual-core, WiFi + BLE)	STM32 series MCUs (ARM Cortex-M4/M7)
Sensor Suite	MPU6050 (6-DOF: accelerometer + gyro)	9–10 DOF IMU (gyro, accel, mag, barometer)
Motor Control	SI2300 N-MOSFETs (for brushed motors, micro-drone scale)	Dedicated ESCs (for brushless motors, larger drones)
Power Input	JST battery connector (likely 1S–2S LiPo)	XT30/XT60 connectors, 3S–6S LiPo (11–22V)
Additional I/O	Basic GPIO, PWM outputs, LEDs, I^2C	Rich I/O: UARTs, CAN, GPS, telemetry ports
Connectivity	Built-in WiFi + BLE (unique advantage!)	External telemetry modules (radio link, GPS, WiFi add-ons)
Approx. Cost (DIY Build)	\$20–30 (ESP32-S3 board) \$3–5 (MPU6050) \$0.50 each MOSFET ×4 + passives → ~\$35–50 total	\$80 – \$250 depending on model and features
Advantages	- Very low cost - WiFi + BLE built-in - Compact design - Great for micro drones / DIY projects	- Professional-grade - Handles brushless motors & big payloads - More sensors for stability - Ready-to-use firmware (Ardupilot, Betaflight)
Disadvantages	- Limited to micro drones (low current MOSFETs) - Only 6-DOF IMU (no compass, barometer) - Requires custom firmware	- Expensive - More complex to integrate - Larger & heavier

4.10 Connection: The **connection** between the flight controller and the ESP is straightforward. After soldering the components according to the provided Gerber file, the modules can be attached as illustrated in the diagram.

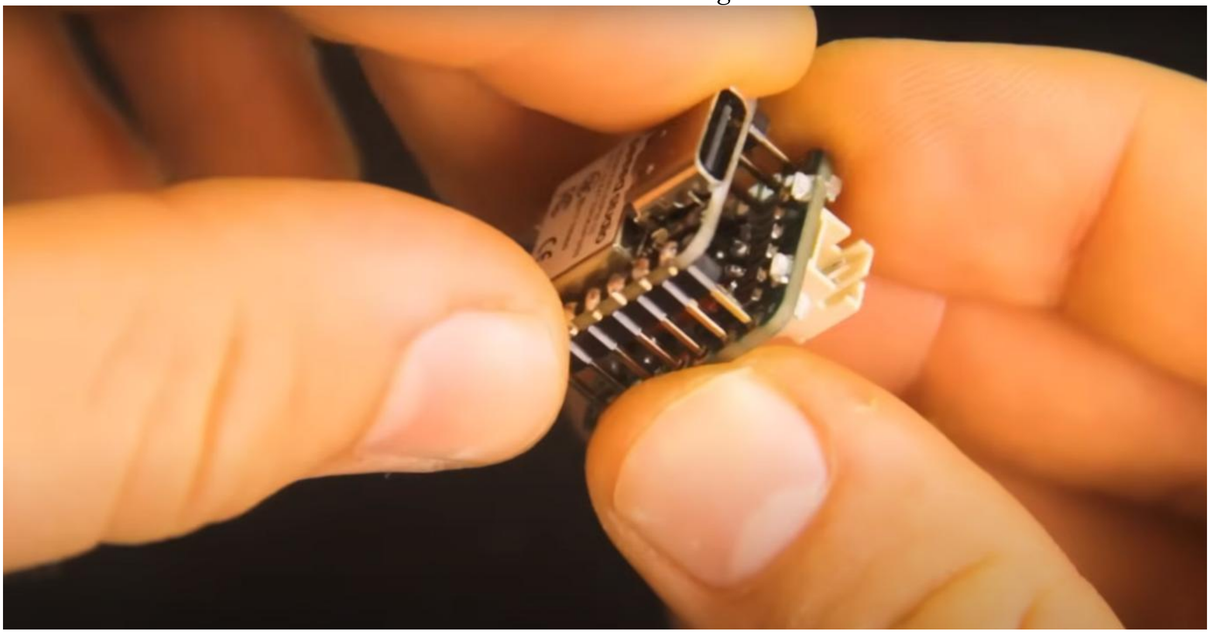

Figure No: 4.7 (Simplified connection between the flight controller and the ESP, following component soldering based on the provided Gerber file.)

Motor connection:

The propulsion system is based on four coreless brushed DC motors connected to a lightweight H-bridge motor driver board. Power is supplied through a micro JST connector from the Li-Po battery, while each motor is connected via two wires—typically one red and one white in this configuration. The polarity of these wires determines the rotation direction of the motor. For proper operation and stable flight, two motors must be connected to rotate clockwise(**CW**) and the remaining two must be connected to rotate counterclockwise(**CCW**). Careful attention is required during wiring to ensure that opposite pairs are set to rotate in opposite directions. Incorrect polarity or mismatched wiring would result in torque imbalance, leading to instability and loss of control. When connected properly, the counter-rotating motor arrangement cancels out unwanted yaw, enabling the UAV to achieve balanced thrust and stable flight dynamics. This motor driver architecture not only ensures reliable two-way control but also allows precise speed regulation through PWM signals, making it well-suited for micro UAV applications where stability and responsiveness are essential.

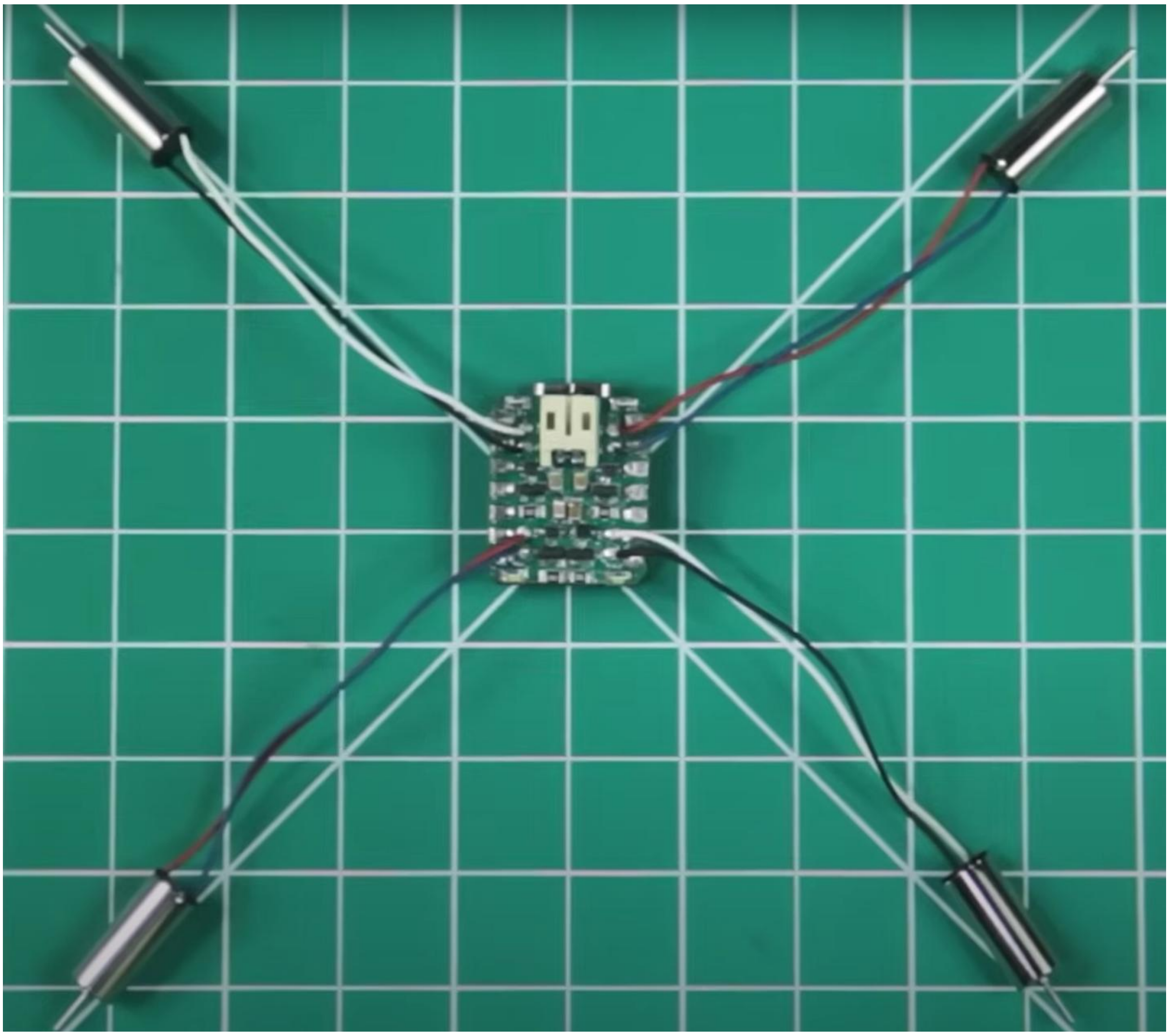

Figure No: 4.8 (Motor driver Connection)

Set up in the housing: This frame is small and light, and it can hold four brushed DC motors, an electronic speed controller (ESC) or motor driver board, and a flight controller. The design is like Lego, which makes it easy to add and remove pieces. Each of the four arms of the frame has a cylindrical slot that can hold a brushed DC motor. This keeps the motor shafts in the right place so you can attach the propeller. In the middle of the frame, there is a distinct spot where you may stack or put the flight controller and the motor driver (ESC) board. This makes it easier to get to the USB port and power connectors to charge and program the device.
This design's ability to work with a lot of different things is quite useful. You can either glue the motors into the arm housings or press them in. You may put the flying controller and driving board in the middle compartment, exactly like you would with Lego bricks. This makes it easier to connect things together and lets you quickly make prototypes or change things. The open design allows air move through the parts, which helps keep them cool. This is particularly important for how well micro UAVs work since it keeps the weight down.

This housing design will make it easy to wire and keep strong so that the ESC and flight controller may be linked on the same platform. This kind of modular design is quite useful for making experimental UAVs since it lets you simply change parts without having to make complicated mechanical changes.

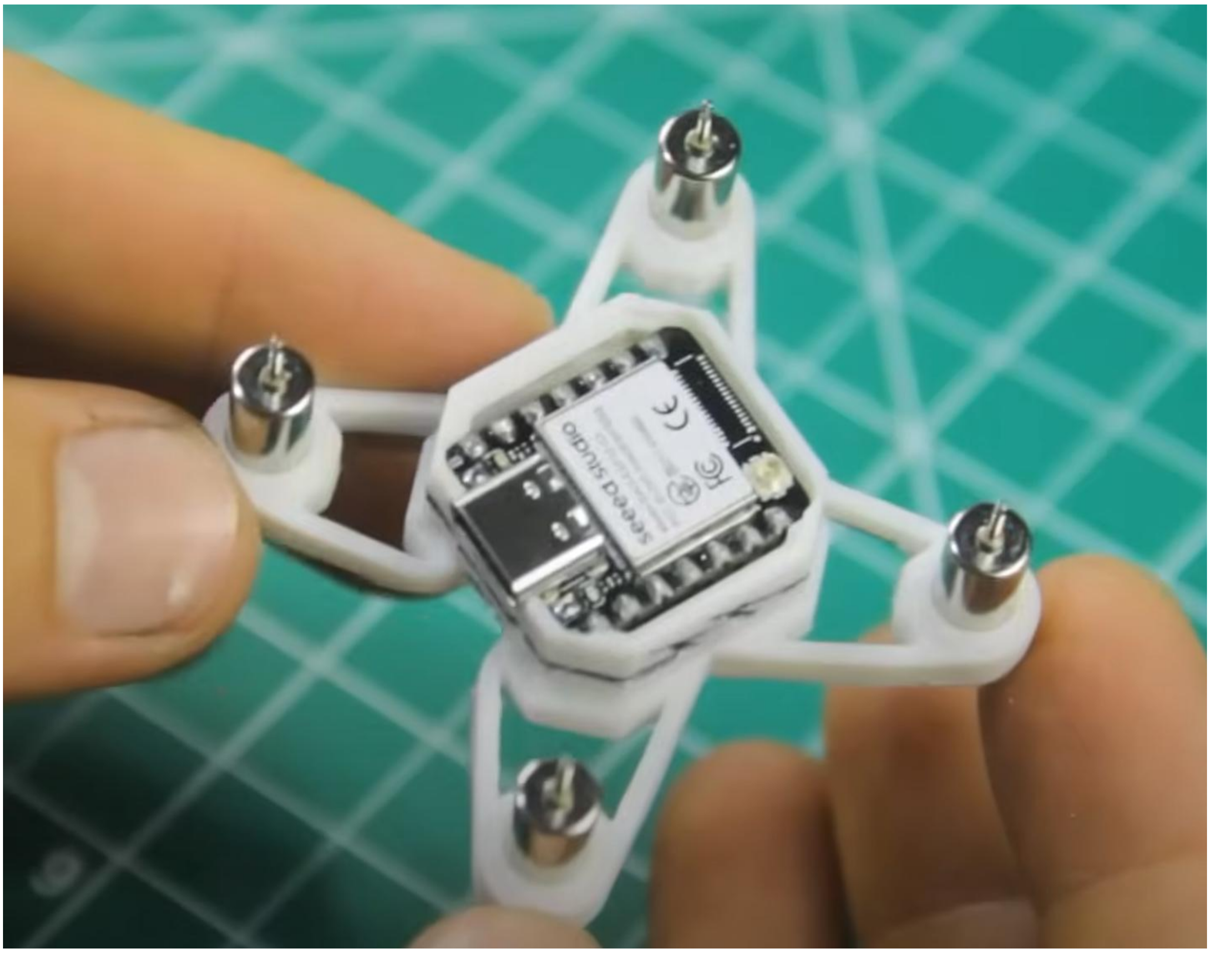

Figure No: 4.9 (Housing setup)

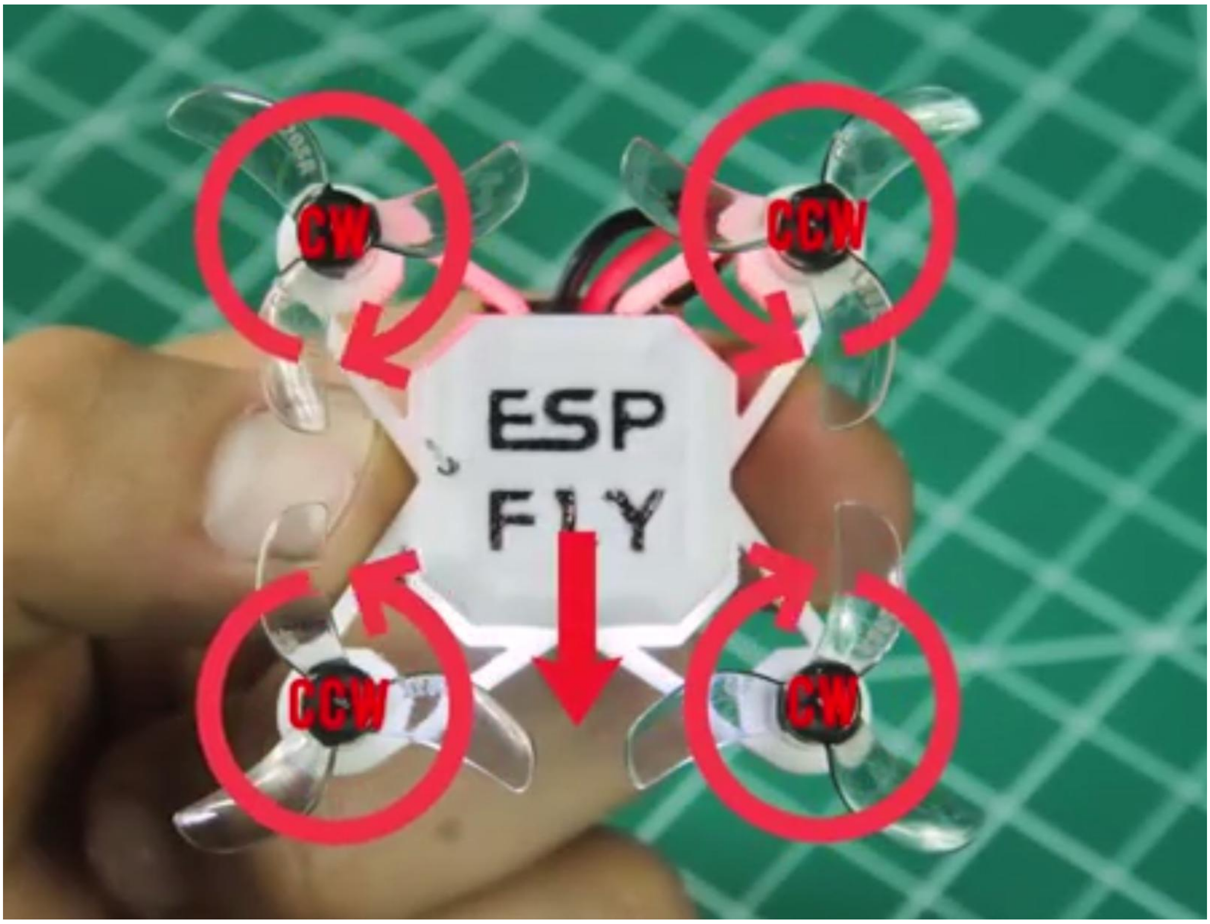

Figure No: 4.10 (Propeller Connection)

Propeller connection: The propeller connections are shown in Figure 4.9. For stable flight, two motors must rotate clockwise (CW) and the other two must rotate counterclockwise (CCW). Care must be taken during installation to ensure that the correct propellers are mounted on the corresponding motors, as incorrect orientation will cause instability or failure to take off. In this design, we selected Gemfan propellers, which are known for their durability and reliability in airborne applications.

Flight Simulation and Control System Implementation for Kokill

4.11 Purpose:

Kokil is a compact (the size of a hand grenade), light (25-30g) platform with a small payload that is meant for short-range reconnaissance and may be quickly deployed in tactical operations.

4.12 Parts and Function:

The flight is stable, and the ESP32-CAM flight controller is attached to the MPU6050 IMU, motors, and sensors. We used a 3D-printed frame to keep the drone light and durable. Kokil has a throw-launch feature (using a special backpackable launcher) that lets the X4-7 recognize free-fall, arm, and launch in just a few milliseconds.

4.13 Flying Mechanism:

Kokil uses rate control to steer and attitude stabilization to keep the flight smooth and steady. It changes the speed of the motors on its own based on the IMU input [6].

Flight Control Simulator results (Apk view)

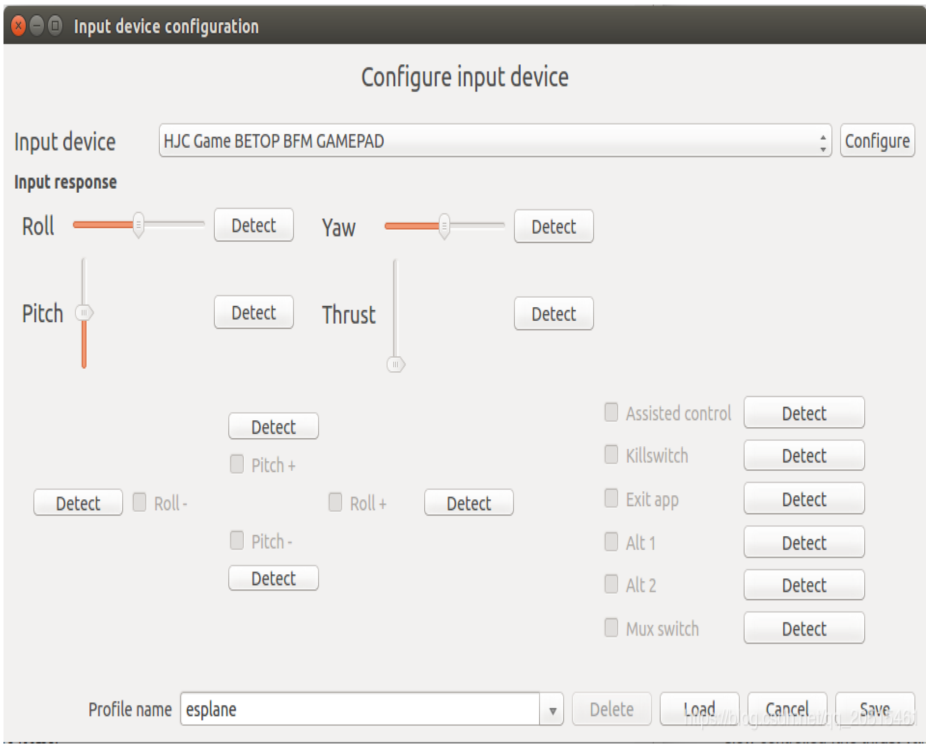

Figure No: 4.11 (Flight Simulation Results for Kokil UAV)

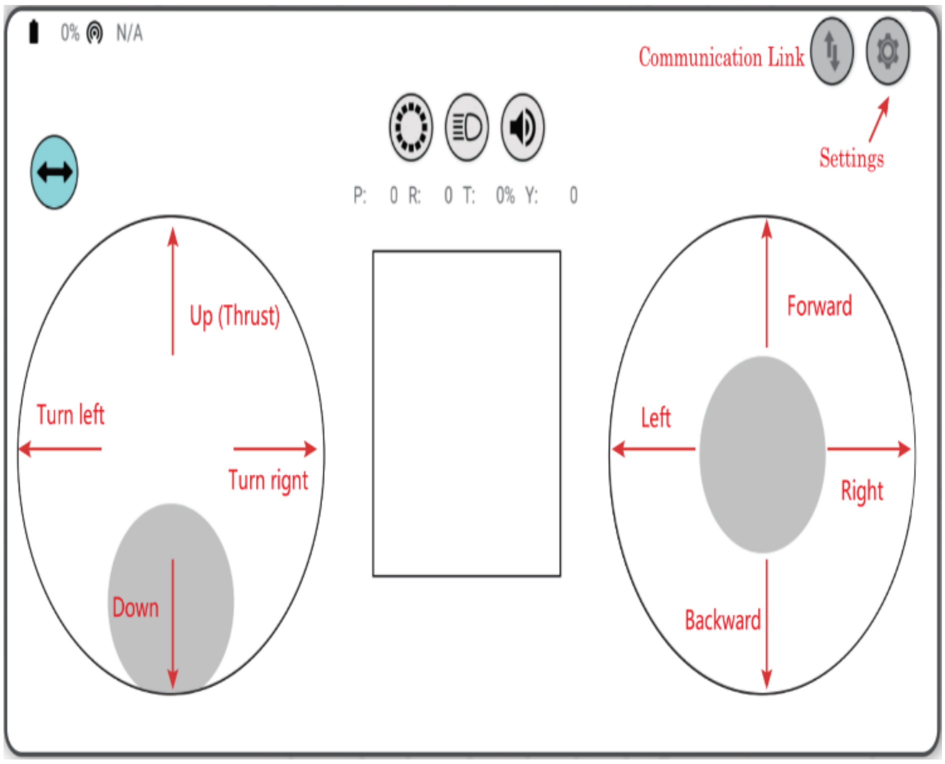

Figure No: 4.12 (Top-Down View of Kokil UAV's Flight Path)

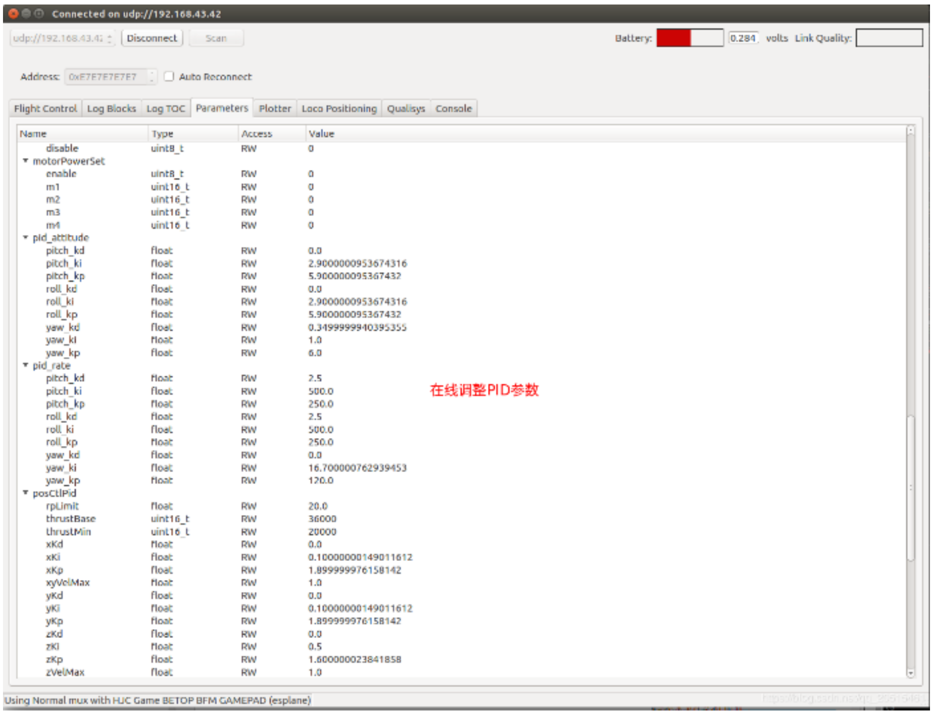

Figure No: 4.13 (Kokil UAV Flight Performance Data)

Figure No: 4.14 (Kokil UAV Test Flight in Urban Area)

4.14 Fall Detection and Code:

The MPU6050 IMU is used to detect changes in acceleration when the drone enters into free-fall. When the free fall is detected, it takes 60 to 120 milliseconds to arm the drone, put the ESC in idle mode, and spin the motors at full thrust.
[** added in the PCB schematics, boom and code link]

4.15 Kolil Design and 3D STL

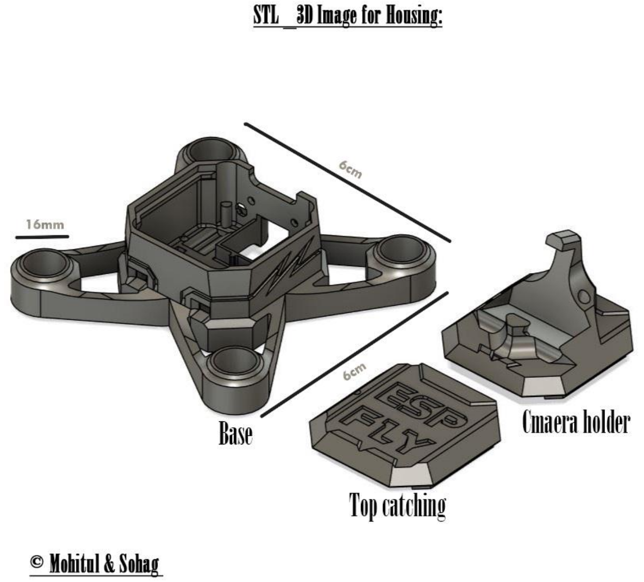

Figure No: 4.15 (3D STL Model for Kokil UAV Design)

4.16 STL 3D Model Components:

1. **Base** (6cm x 6cm, 16mm high):

i The base is the middle part of the casing. It's the base of building to which the flight controller and motors will be attached. This part is typically designed to create a stiffening frame, so that the components of the drone won't move during a flight.

ii The height of 16mm probably shows the installation space of internal devices and a frame to fix on.

2. **Top Catching** (5cm x 5cm):

i This part is meant to be placed over the base, most likely to shield the flight controller, motors, and other parts from dust. It can act as a cover or a cap to secure the parts inside the housing in place to keep them from moving.

ii It probably also serves some aerodynamic purpose in minimizing drag, or protecting the internal components of the drone from environmental factors like dirt or debris.

3. Camera Holder:

i Drone housing Camera Mount UAV Parts for RC drone Product Description The camera holder is an indispensable part of the drone housing that holds the camera you are using for FPV flying or recording.

ii It is designed to maintain a stable and fixed camera reducing vibrations which create shaky images.

iii There could be a place to put the small camera module used, for example, in ESP32 to stream or record the video from an small-sized drone.

4. Battery Holder

i Battery holder – This is required to house the power source of the drone (LiPo battery in most cases) firmly in place.

ii It is typically molded to the exact battery dimensions which fit snugly and securely without fear that the battery will slide out or rattle during flight due to an oversized front aperture or flat shape that is required to fit a range of battery shapes and sizes.

iii The battery holder is built into the body, suggesting that it is meant to be an element

iv in the very structure of the aerial vehicle.

5. Key Features in the Design:

i 24mm * 24mm Size: It's probably the footprint of the housing area; there must be space for the camera, flight controller, and battery.

ii 16mm ABOUT HEIGHT: The height of it means there is clearance for internal fitting, cooling, or cable routing.

iii Screw Holes: There are screw holes that can be seen in the design, which are used to lock the motor mounts, camera, and flight controller.

6. Weight: The Total weight of the drone is estimated to be only 16g, and while adding the camera and battery, it will be a total of 25g for Air Born [12].

4.17 Code & APK installation:
Environment & prerequisites (Windows PowerShell)

Installation and Setup Instruction

The firmware for *Kokil* was developed using the Espressif ESP-IDF framework. To begin, the ESP-IDF environment must be installed and initialized through the official PowerShell setup tool (download link will be provided). Once installed, the firmware can be compiled and uploaded to the board. The recommended flashing command is:

```
idf.py -p <COM_PORT> -b 1200000 flash monitor
```

where <COM_PORT> corresponds to the USB port of the ESP board. In some cases, adjustments may be required depending on the ESP-IDF version or the specific ESP-Xio hardware revision. If errors occur, the baud rate can be temporarily reduced to 115200.

After flashing, the device automatically connects to the configured Wi-Fi network and exposes a lightweight HTTP interface for control. The system can then be synchronized with a mobile application by scanning a QR code that contains either the device IP address or a hosted APK download link. Once installed, the Android application communicates with the drone over Wi-Fi, enabling flight control directly from a smartphone.

APK QR Code:

Figure No: 4.16 (APK QR Code)

Result Analysis for Kokil:

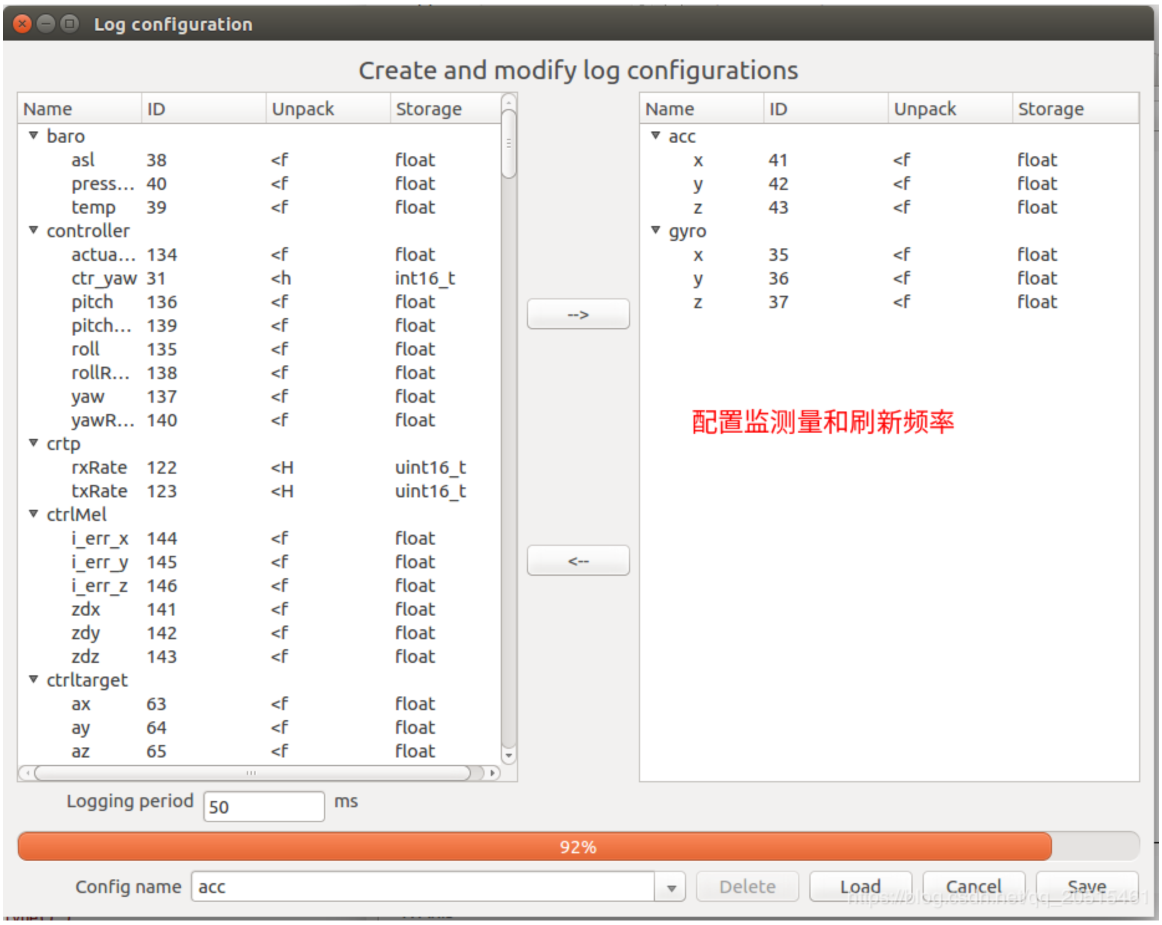

Figure No: 4.17 (simulation result)

This shows the simulation result
The simulation results for Kokil demonstrate how sensor logging, motor thrust performance, and control input mapping influence overall system stability and flight capability. The logging configuration interface confirms that multiple flight variables, including accelerometer, gyroscope, pitch, roll, and yaw, were successfully monitored and recorded in real time. This provides a comprehensive dataset for evaluating stability under different flight conditions and allows closed-loop controllers, such as PID algorithms, to be tuned more effectively.

Motor thirst chart:

Figure No: 4.18 (Motor thirst chart)

The motor thrust-to-weight chart further validates the propulsion system design. Experimental results indicate that Kokil's micro brushed DC motors generate thrust within the "Flyable" to "Better" range (thrust-to-weight ratio between 1.2:1 and 1.9:1). This confirms that the system is capable of sustained indoor flight with sufficient lift for maneuvering and light payload carrying. The ratio also highlights the limitations of micro UAVs, as heavy payloads or aggressive outdoor maneuvers would require higher thrust margins typically seen in "Turbo" or "Rocket" categories.

The control mapping diagram illustrates the integration of multiple input sources into the Crazyflie framework. Raw inputs from devices such as joysticks, Kinect, Leap Motion, or socket interfaces are first normalized and scaled before being multiplexed into the flight control system. This architecture ensures that *Kokil* can accept commands from a variety of experimental control modalities, making it adaptable for human–machine interaction studies, gesture-based control, or autonomous navigation testing.

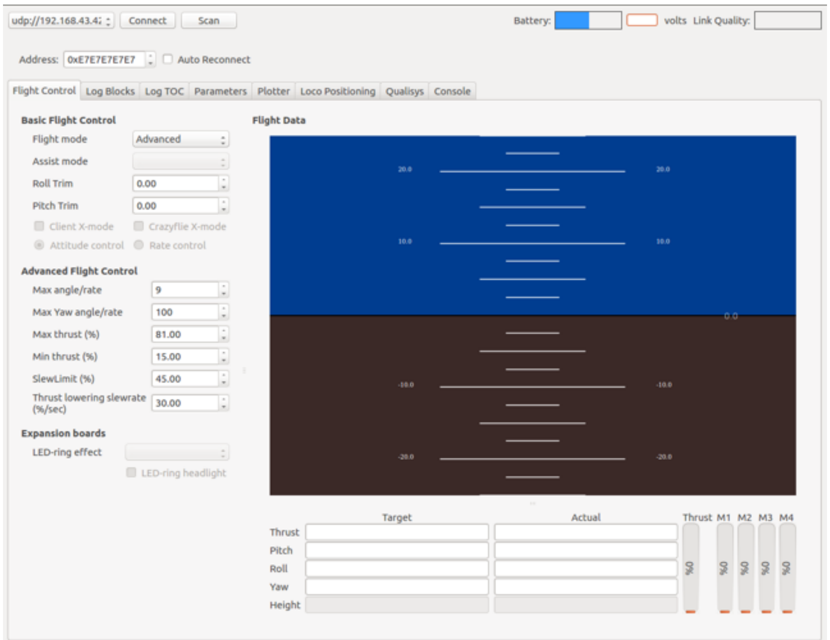

Figure No: 4.19 (autonomous navigation testing)

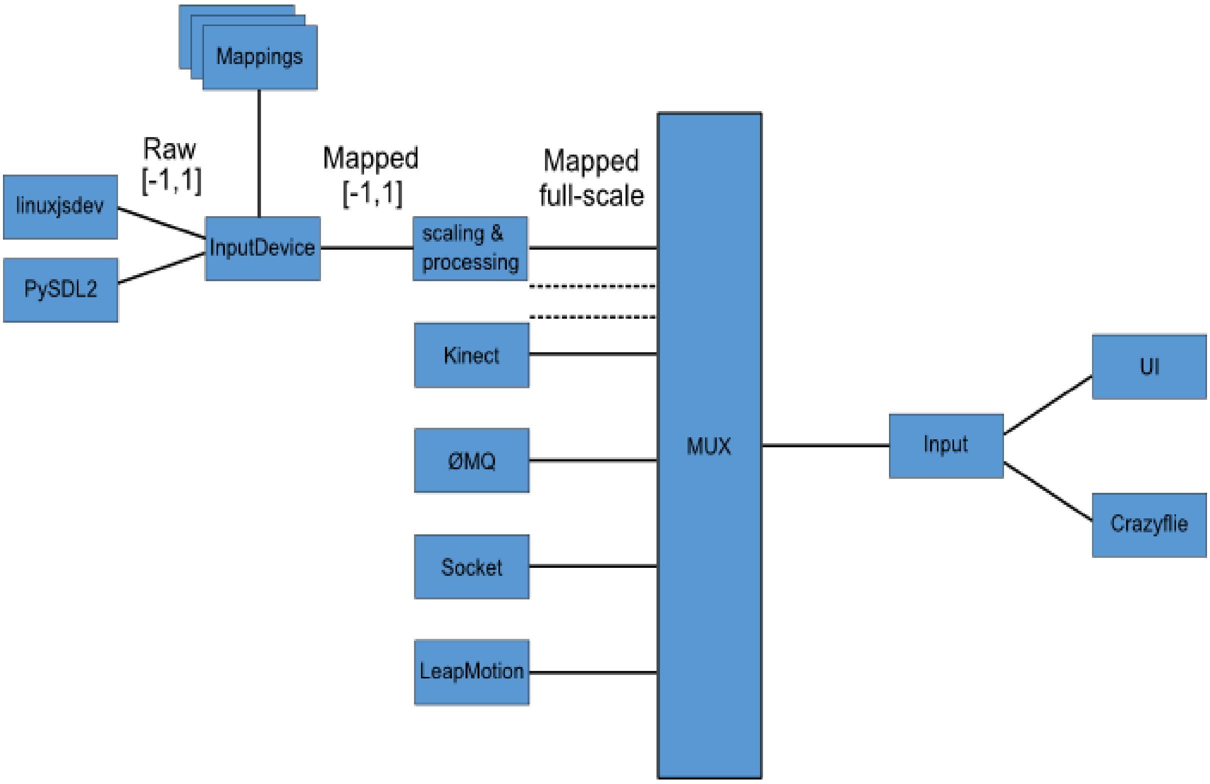

Figure No: 4.20 (Mapping diagram)

Design and Functionality (Kokil)

Integration of ESP Free Flight Controller System for Open-Source Programmable Drone(Kokil)

The drone design described herein utilizes an open-source, programmable controller, enabling dual-control functionality via both a mobile phone and a traditional radio controller system. This approach leverages the ESP Free Flight Controller, which can be seamlessly integrated into the system for autonomous flight control.

System Setup and Installation Process

1. **Software Installation:**
   To configure the ESP controller for flight, users must first download and install the necessary software, which can be accessed from the official Espressif ESP Drone documentation. Upon installation, users may need to adjust the communication baud rate, typically set to 1,000,000 bps, depending on the board version in use. For ease of programming, the **ESP C3 version** is recommended due to its straightforward code-upload process.

2. **Mobile Application :**
   Users need to install a mobile app in addition to setting up the controller so they can control the drone. The app works on both Android and iOS devices. Before you install it, you need to turn on developer mode on your phone. Depending on the model of phone you have, you may need to make some small changes to the settings. The official ESP Drone GitHub repository has further information and the app link: ESP Drone GitHub repository.

3. **Flight Readiness:**
   Once the software and mobile application are properly installed and configured, the drone is ready for flight operations.

PCB Design and Manufacturing

The drone's printed circuit board (PCB) design files are available for download in Gerber format, which can be used for manufacturing the PCB. These files can be accessed through the following Google Drive link.

When placing an order with JLCPCB for PCB production, it is recommended to include additional antenna components, which will facilitate the process of surface-mount device (SMD) soldering.

4.18 Drone deployment Mechanism:

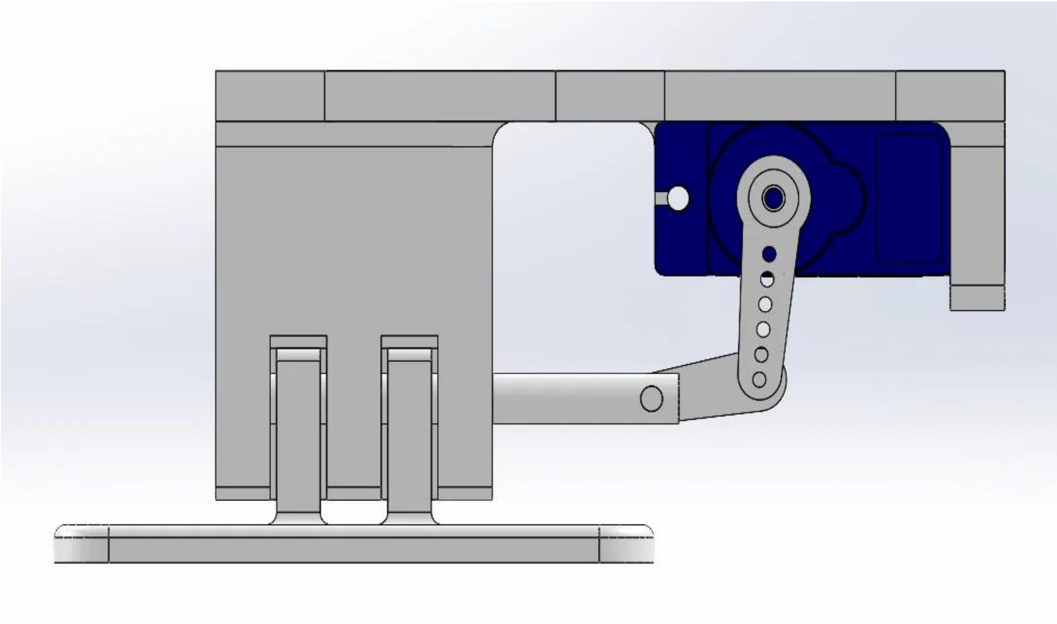

Figure No. 4.21 (Deployment Mechanism for Kokil UAV)

4.19 Drone Payload Release Mechanisms
Drones. The key to the successful operation of a drone payload release device lies in its actual release mechanism, which is utilised across a broad range of industries and uses, such as aerial delivery systems, environmental monitoring, search and rescue. Such mechanisms enable drones to drop off cargo or scientific instruments in a certain place with precision, in both commercial and research settings.

4.20 Servo-Actuated Release Mechanism
A popular mechanism use in the release systems of drones is to employ a servo motor to drive a lever or arm to discharge a drone payload. Mechanically, the device generally includes the:
i. Servo Motor: The soul of the system, a servo motor is used to supply some kind of mechanical movement to help release the thing. Once activated, the servo motor rotates and drives a lever or arm.
ii. Lever/Hook System: Attached to the servo motor, the lever or hook is used for

Conclusion on Kokil

Advanced engineering, applied physics, and real-world problem-solving in the field of aerial robotics have come together to create and deploy UAVs, especially models like Kak and Kokil. UAVs have had and will continue to have a revolutionary impact on both the military and civilian sectors, as evidenced by the historical progression from early pilotless aircraft to today's incredibly intelligent and agile drones.

As explained in this paper, Kokil shows how contemporary drones can be designed for particular tactical uses, making use of lightweight components, small electronics, and advanced control algorithms to provide dependable performance in challenging conditions. Modular payload options, strong communication systems, and extensive sensor suites guarantee adaptability for a range of missions.

Kokil demonstrates the potential of small UAVs in practical situations by comprehending and resolving the engineering difficulties of stability, power management, and deployment mechanisms. Further advancements in UAV design and use are made possible by the simulation and prototyping work described here.

The next generation of aerial vehicles will be influenced by the lessons learned from projects like Kokil as UAV technology advances, allowing for more accurate, effective, and significant use in the commercial, military, and humanitarian sectors. UAVs have a bright future ahead of them; the only things limiting their potential are our creativity and technological know-how.

Kak – Concept

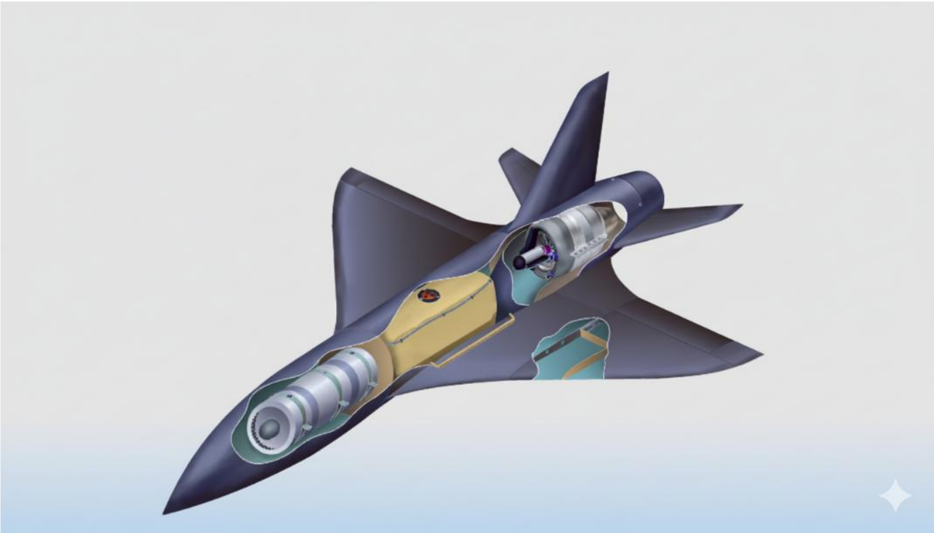

Figure No: 4.22 (Kak UAV Conceptual Design)

The Kak UAV is a high-tech tool that can be used for a wide variety of purposes – for military reconnaissance, or civilian ones like monitoring the environment. Kak A flexible and affordable solution, the Kak offers modular design, feature options and state of the art technology. This chapter outlines the key components and connections of Kak, along with how much it costs. It emphasizes how good it can be at many different jobs and how readily it can change engines to suit different missions.

4.21 Key Components of Kak UAV and Their Applications.

Jetson Nano for AI-Based Navigation

Figure No: 4.23 (Jetson Nano for AI-Based Navigation in Kak UAV)

The Jetson Nano is a small but powerful AI computer that is the key compunent of Kak's ability to act on its own. Kak can do this by himself, without anyone continually watching over him. He can utilize the Jetson Nano to move, read data from his sensors, and make quick decisions. AI-enhanced technology might assist Kak get adapted to the constantly changing environment and be able to function in tough settings and conduct a number of various things, like surveillance, reconnaissance, and detecting targets.

When you can plainly see that something in the surroundings has changed and you need to act quickly, like following after something that is moving or avoiding a barrier, Kak is really helpful on Jetson Nano.

4.22 Hybrid Propulsion System: Engine Flexibility for Mission Needs

Kak's hybrid propulsion system is one of the most amazing things about it. It strikes a balance between performance and adaptability. The design of the Kak's housing is vital for its future because it lets us change engines depending on the task. For example, it can be a jet engine for fast, long-distance flights or an electric motor for quieter, more energy-efficient performance in tactical situations.

Engins:

Jet Engine: For operations that need to fly far and fast Kak can fly faster than 1,000 km/h because it has a jet engine. This makes it easy to set quickly and execute aerial bombing and military reconnaissance. The Kak can travel long distances quickly when it has to since it has a lot of energy. Mission for Stealth and Tactics with

Electric Motor Fume motors make noise and smell bad, therefore the electric motor feature helps Kak undertake sensitive covert or covert observation and urban reconnaissance for a long time with little noise and power utilization for sensitive mission operations.

Application: Kak can adapt to both **high-speed, long-range military missions** and **stealthy, energy-efficient civilian missions**, depending on the operational requirements.

Cost:

- **Jet Engine: $1,500–2,000**
- **Electric Motor: $300–500**

4.23 Lightweight Carbon Fiber Frame

The frame and body of Kak are made from carbon fiber or high-strength composites, which combine light weight with durability. These materials ensure that Kak is both aerodynamic and resilient, capable of withstanding environmental challenges without compromising performance.

- Application: The lightweight design of Kak allows for extended flight times and improved maneuverability while also providing the strength needed to endure harsh weather conditions and rough landings.
- Cost: $500–800

4.24 Battery and Power System

Depending on the mission and its engine, the power systems vary, if it's an electric motor bike engine, then Kak will be powered by **Lithium Polymer (LiPo)** batteries. But if it's a jet fuel engine the we need to put jet fuel to power it up

4.25 Modular Payload System

The modular payload system is one of Kak's most important features, allowing the UAV to carry a variety of payloads based on the mission's needs. Whether it's high-definition cameras, thermal imaging sensors, or even smaller UAVs like Kokil, Kak can be reconfigured to serve a wide range of tasks.

- Application: The payload system makes Kak adaptable for surveillance, border monitoring, environmental studies, and military reconnaissance. By swapping payloads, Kak can switch between different tasks with ease.

- Cost: $200–500

Table 4.4: Total Estimated Build Cost of Kak UAV:

Component	Estimated Cost (USD)
Jetson Nano	$100–150
Jet Engine	[To be discussed in Ch. 11]
Electric Motor	[To be discussed in Ch. 11]
Organic Leather Coating	$200–400
Frame and Body	$500–800
Battery and Power System	$300–500
Sensors and Payload	$200–500
Total Estimated Cost	**$2,800–4,000**

Engine Swapping and Modular Housing for Enhanced Mission Adaptability

Engine Swapping and Modular Housing for Increased Mission Flexibility
Kak has a versatile design, one of the signature features is the ability to "swap out" engines is that it can be repurposed quite freely, making it among other things a good 'A away' platform and a good launch platform for Roast or ICS. And unlike most UAVs, Kak can easily switch between a jet engine or an electric motor, based on mission requirements. This interchangeability of engines to meet operating needs dramatically improves Kak's versatility, performance and cost-effectiveness.
In this chapter we will cover how swapping engines will work, what is a modular housing system, and what does it bring in terms of mission customization.

4.26 ENGINE SWAPPING: KAK MODIFICATION FOR MISSION ADAPTABILITY

Kak's hybrid propulsion system lets us switch between a jet engine and an electric motor based on the tasks required. This ability is the one that makes Kak flexible and helpful for a wide range of tasks, from quick, long-range search missions to low-power, undercover surveillance.

4.27 Jet Engine for High-Speed and Long-Range Missions:

Figure No: 4.24 (Jet Engine for High-Speed Missions in Kak UAV)

4.28 EV Motor Bike Engine:

When our mission required a long distance coverage but we've spare time there we can use the motor bike engine and offcourse it will save lots of money for the mission

Best For:

i. **Military operations**
ii. **Long-range surveillance**
iii. **Tactical air support**
iv. **Electric Motor for Stealth and Tactical Missions:**

Figure No: 4.25 (Electric Motor for Stealth Missions in Kak UAV)

For energy-efficient operation, we can switch to the **electric motor**. This motor is perfect for missions that require **low noise**, such as **surveillance**. The **electric motor** allows Kak to stay in the air longer while using less fuel, making it a more cost-effective option for extended operations.

How Engine Swapping Works:

Mission Customization: Depending on the task at hand, the operator can easily choose between the **jet engine** or **electric motor** to optimize performance.

Quick Reconfiguration: The **modular design** allows Kak to be reconfigured quickly. This flexibility means Kak can handle multiple mission profiles without needing separate UAV systems for each one.

4.29 Modular Housing System: Supporting Engine Swapping and Payload Flexibility

The idea of modular housing is used in Kak's design. You can easily switch engines and add different payloads to do a lot of different things. This kind of technology makes sure that the UAV can modify and adapt to any task it needs to do.
The ability of modular engines to adapt Housing: With the Kak housing system, it's easy to put in and take out both the jet engine and the electric motor. This makes it easy to change the propulsion systems in the modular housing without having to wait long. You may also alter the Kak so that it can do new things without losing its ability to work.

Quick Engine Installation: The housing system lets engineers or operators switch between propulsion systems in just a few hours, depending on what the task requirements.

Because the construction is modular, it's easy to change the engine and connect anything else that needs to be connected, such electricity, gasoline, and control systems.

The Kak payload system is modular, so the UAV can carry different sensors and tools for different jobs. It's easy to change the Kak payloads so that they can hold things like high-resolution cameras, thermal sensors, or even Kokil UAVs that can be launched on surveillance missions.
Flexibility: Kak can carry a wide range of payloads, depending on the job. This could be for gathering information, scouting, or watching.
Kak can utilize everything it needs to complete its job, such thermal imaging, radar jamming tools, and more.

4.30 Benefits of Engine Swapping and Modular Housing

There are many benefits to the modular housing system and engine swapping:
Some of the features are: Flexibility: Kak can be used for a wide range of missions without needing more than one UAV. Kak can handle anything, from a high-speed military operation to a secret surveillance mission.

Cost-Effectiveness: The ability to use the same platform for different types of missions means that you don't need as many drones, which saves money on both buying and maintaining them over time. Also, Kak is made up of modules, so operators only need one system, which lowers costs even more.

Successful Missions: We can make the mission more likely to succeed by adjusting the UAV to fit the needs of the mission, such as swapping out the engine or changing the payload. Kak can work in a variety of situations, including high-speed aerial operations and low-profile, low-noise surveillance.

Fast switching of engines and payloads: Kak is useful in situations where a quick deployment is necessary because it lets you do this. The modular design makes the UAV ready for missions all the time, no matter where it is.

4.31 Future Expansions: Engines and Payloads Kak Expansion.

With the growing need of more specialized UAVs, future enhancements of engine-swapping and modular housing capabilities of Kak may involve:

Extended Engine Capabilities: More powerful or efficient engines may be introduced to offer extra mission profiles, including jett engines to offer longer missions or electric jet engines to offer high speed and low energy missions.

Advanced Payloads: Future Payloads may have more specific systems such as LiDAR sensors, biological sampling instruments or chemical sensors to monitor the environment and conduct scientific studies.

Table 4.5: Comparative Table:

Feature	Shahed-136	Kak UAV
Engine	MADO MD-550 piston engine (50 hp)	Hybrid system: Jet engine + Electric motor
Speed	185 km/h (115 mph)	Jet mode: Up to 1,000 km/h; Motor mode: 40–150 km/h
Range	Up to 2,500 km (1,550 miles)	Jet mode: 0.5–2 hours; Motor mode: 4–6 hours
Payload	High-explosive warhead (30–50 kg)	Explosives, Kokil deployment, surveillance sensors
Navigation	GLONASS-based	Jetson Nano (AI-based, real-time vision)
Launch Method	Rocket-assisted take-off	Vertical take-off and landing (VTOL)
Stealth	Basic aerodynamic shaping	Organic leather coating for radar absorption and stealth
Reusability	Single-use (disposable)	Reusable, multi-mission capability
Cost per Unit	Estimated at $30,000–80,000	Approximately $2,800 (initial build cost)
Cost per Mission	Equivalent to unit cost (single-use)	$10–30 per flight
Operational Use	Military strikes, one-time use	Military surveillance, border monitoring, wildlife observation

4.32 Kokil – Deployment from Kak and Tactical Role

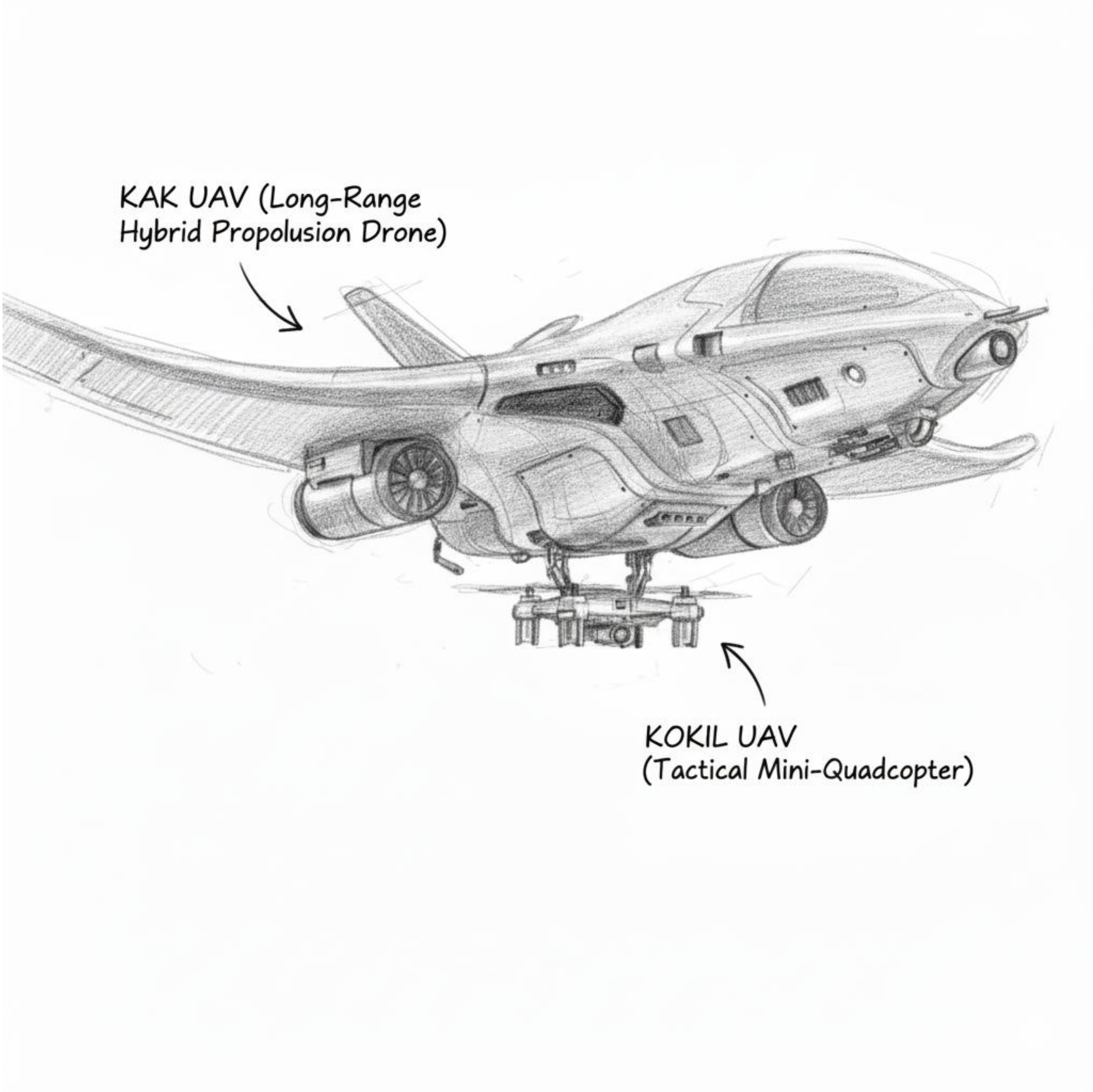

Figure No:4.26 (concepto f scktce for dual drone system)

The Kokil UAV is a small form factor device that's designed to be deployed from the Kak UAV, conferring upon it a range of capabilities suited to a number of missions. Whereas Kak is a jack of all trades that can operate at distance, Kokil is focused on cracking into tighter, more discreet areas where larger drones would not only struggle, but may also be detected.

4.32.1 Purpose and Design:

Mission The Kokil is designed to observe when the cover and flexibility are important, mainly for reconnaissance and surveillance. It is smaller, lighter and more maneuverable than the Kak and as such is the ideal tool for collecting intel in areas where a subtler approach is required. If the mission calls for low-level flights over enemy lines or maneuvering in tight confines, the Kokil can do the job without attracting notice [14].

4.32.2 Deployment from Kak:

What makes the Kokil particularly useful is that it's deployed from the Kak UAV. The kak carries the kokil to the area close to the mission and then releases it at its convenience and from a safe distance. This gives the Kokil the ability to enter spaces which could be too dangerous or difficult for larger drones to traverse. It's kinda of like you send in a scout, keep your main force (Kak) in the back [15].

4.32.3 Tactical Advantage:

Its small size and agility is the primary strategic advantage of Kokil. Kak is ideal in such a high impact mission and Kokil is like having a little bolt precision bitch bending over on all four holes getting the job down. This is especially required in delicate or low impact conditions. Kokil can be used in urban setting, forest or mountainous range, where the bigger drones become uncontrollable [15].

4.32.4 Lightweight Build and Cost-Effectiveness:

The other feature of the Kokil is making it one of the least expensive compliance weapons on the game, as well as the lightweight nature. That renders it economical where the more expensive drone could be excessive when it comes to missions. It provides long-term business and regular monitoring within a cost-efficient cost. Even though it is small, it is durable and does the mission without performance penalties.
This study has managed to examine the design, development and Engineering stages of two state of the art UAVs; Kak, a long distance drone operating under hybrid propulsion and, Kokil, a small quadcopter used in tactical intelligence. "MAVs are the future of UAVs, and may be a game-changer on the tactical level, as well as find use in the commercial and humanitarian domains.
The Kak UAV equipped with the hybrid propulsion engine is a demonstration of this form of flexibility, leaving the device at liberty to alternate the jet and electric propulsion to meet the mission conditions. The ability to fly fast and high, or fly low and slow during a long-range mission or on a covert and fuel-efficient mission makes it an invaluable platform to all types of missions including military reconnaissance and environmental monitoring. The Jetson Nano's advanced autonomy and organic leather skin give it stealth-like capabilities, which let Kak work in the most dangerous places. This is a big step forward from typical UAV systems.
The design of the Kokil UAV, on the other hand, The Kokil UAV was designed to be compact, quick to deploy, and flexible, making it useful for tasks that need to be done in confined or restricted regions. It is a useful tactical surveillance tool because it is light and easy to move around. It can also be used as a Kak UAV, which means it can be used in various situations and collect intelligence in different ways. But like with any new technology, there have been a lot of obstacles to solve during the research

process, such making prototypes, testing them, and dealing with logistical issues like supply problems and shipments that get stuck at Customs. Even if there are ways to get over these problems, such getting supplies from other countries, these problems can be used to show how important it is to improve local infrastructure and resources to make future UAV operations in the developing world possible.

This research could also be expanded by examining the ethical, legal, and regulatory issues surrounding the deployment of UAVs, especially in military and surveillance applications. The debate about long-term scalability, maintenance costs, and city insertion continues to be a key issue for future growth.

In conclusion, both the Kak and Kokil UAVs create new possibilities for the growth of UAV technology in a variety of fields. Unmanned aerial vehicles (UAVs) are vital tools for military, commercial, and humanitarian activities because they are very useful, flexible, and cost-effective. As UAV technology gets better, the insights acquired from this research will be very important for making UAVs that are sustainable, versatile, and useful in real life. The next step is to improve this proof of concept and deal with the greater problems that come up when drones are used in many various ways, such as with infrastructure and regulations.

Chapter 5

Engineering Standards and Design Challenges

5.1 Compliance with the Standards

5.1.1 Software Standards

In UAV development, adherence to hardware standards is critical for ensuring safety, durability, and interoperability. For Kokil and Kak, all major hardware subsystems were designed with reference to **IPC standards for PCB fabrication (IPC-2221/2222)** and **IEC 62133 safety guidelines** for Li-Po battery handling. Compliance with **RoHS directives** was also considered, ensuring that components met global environmental and material-safety requirements.

- Use of open-source platforms (Arduino/ESP-IDF for ESP32).
- Compliance with IEEE software development standards for embedded systems (IEEE 730 for software quality, IEEE 828 for configuration management).
- Coding standards (consistent modular C/C++ for microcontrollers, MISRA-C for safety-critical embedded systems).

5.1.2 Hardware Standards

One of the hardest parts of this project was to choose proper hardware. Early on ATmega chipsets were also contemplated, but their absence of integrated gyroscopes and accelerators precluding them as flight-controllers. As a way to address the motion-sensing needs, the team picked up the MPU-6050 sensor, a single unit that integrates the functions of accelerator and gyroscopes into a small size. In the case of the main controller, we chose to use the 805 series chips because they are supported by research documentation and uses in embedded applications.

Availability of components was a big problem in Bangladesh. A number of components needed have been unavailable or so hard to procure locally that it is prohibitively expensive. This limitation necessitated the use of external suppliers which caused logistical latencies as well as highlighted the significance of supply-chain feasibility in the design of hardware.

In the case of PCB fabrication, the team first developed negotiations with local companies like Walton. Nevertheless, the majority failed because of the small batch size, and some could not be used in multi-layer fabrication. Finally, fabrication was subcontracted to JLCPCB (China) that assured adherence to IPC-2221 (generic PCB design standards) and IPC-6012 (qualification and performance specification of rigid PCBs). This move ensured uniformity in quality, electrical performance and durability.

Regarding assembly practice, the project team invested in a soldering station and learnt both through-hole and surface-mount device (SMD) soldering. The IPC-A-610 standards used to guide training define acceptability of electronic assemblies. This was done practically, though not easily, and the end result was the boards which were built to meet internationally accepted workmanship standards.

In general, adhering to the standards of PCB fabrication, component quality certification, and assembly, the hardware development process, in addition to satisfying the functional needs of the project, created an opportunity to ensure scalability, safety, and reliability of UAV systems. design continued to be dependable and producible.

5.1.3 Communication Standards:

UAV operations rely on reliable communication to assure both safe flight control and viable data transmission of the payload. Communication subsystems in this project were proposed in accordance with the set international standards of wireless communication and data protection.

The XIAO ESP32-S3 microcontroller is the central element of the design of Kokil, with IEEE 802.11 (Wi-Fi) and Bluetooth Low Energy (BLE 5.0) connectivity. These standards make it compatible with the common communication devices, data exchange with low latency, and power saving. Wi-Fi was favored as mission-critical control because it has greater bandwidth and real-time telemetry.

The UAV should also have secure and interference free communication in the tactical operations. To overcome this the project also included the AES-128 encryption of data packets as a best practice in wireless protocols of security (WPA2). This will provide both flight commands and sensor information with privacy and minimize chances of being intercepted or loss.

In the case of long-range operations (Kak UAV), LoRaWAN (IEEE 802.15.4) and 5G cellular modules were also a possibility in the future. Such technologies increase the range of operations, enhance the stability of the network, and correspond to the emerging world UAV communication networks.

Hardware was also designed based on Electromagnetic Compatibility (EMC) standards (IEC 61000 series) to keep power electronics, sensors, and radio systems of the UAV as non-interfering as possible. This guaranteed that the propulsion system, and communication subsystems would run simultaneously without a degradation of signals.

Using the standards of IEEE wireless networks, WPA2/AES encryption protocol as well as EMC the communication system of Kokil and Kak was developed in a way that it is secure, interoperable and reliable in the different mission conditions. The measures bring the project in line with the professional UAV development practice and regulatory requirements of safe deployment [19].

5.2 Impact on Society, Environment, and Sustainability

The development and the introduction of UAVs like Kak and Kokil can have a great impact on society, environment, and long-term sustainability. These effects are not only technical but they also affect humanitarian use, ethical concerns and environmental accountability.

5.2.1 Impact on Life:

UAVs like Kak and Kokil can make society and environment more secure

Safety & Risk Reduction:

They can fly where humans can't — into collapsed buildings, conflict zones, or flooded areas for search and rescue. This keeps first responders out of danger. In the military, they reduce the need for manned aircraft and help save lives.

Everyday Use:

Drones are now used in farming to check crops or spray pesticides, in infrastructure monitoring, and in medical delivery. Kokil, being small and agile, could deliver medicine to remote villages, watch traffic, or provide fast local surveillance.

Healthcare & Relief:

In disasters, they can drop vaccines, food, or emergency drugs where roads are blocked. Their low cost and quick response can save lives when time is critical.

Ethical Concerns:

Misuse is a real risk — from spying on civilians to data theft or weaponization. Strong rules and oversight are needed so drones help people instead of harming them.

5.2.2 Impact on Society & Environment

The use of UAVs like Kak and Kokil affects the society in both positive and problematic ways. On the one hand, UAVs are socially and economically beneficial, whereas on the other hand, they lead to the emergence of ethical and environmental issues that have to be managed cautiously.

Impact on Society:

UAVs have spread rapidly in terms of agricultural, security, disaster management and infrastructure inspections. Indicatively, due to its low cost and small size dimensions, Kokil can be applied in urban surveillance, traffic monitoring, and precision agriculture to allow communities to have access to real-time information and enhance decision-making. Kak has a hybrid propulsion system, making it possible to be used in monitoring the border or conducting environmental surveys or humanitarian missions in which a conventional manned system would be prohibitively expensive or hazardous.

Nevertheless, the UAVs have their own social issues especially regarding privacy and security. The prevalence of the use of drones in surveillance may bring about the issue of data abuse, surveillance at all times and loss of individual rights. Regarding the military, drones are capable of transforming the character of warfare by facilitating remote warfare which casts doubt on accountability and the safety of the civilians.

5.2.3 Ethical Aspects

Ethical issues of UAV development and use go beyond the technicals of the UAVs. This project experienced two different ethical dimensions, which were the issues concerning the use of technology and the issues associated with systemic barriers in the research settings.

Ethics of UAV Technology Use:

Drones like Kak and Kokil are dual-use technologies by nature. Though they have humanitarian applications as well — disaster relief, medical supply dissemination, environmental monitoring — they could also be used for spying, privacy invasion or offensive military actions. This dual-use nature raises questions of responsible innovation in which engineers must balance potential societal benefits with misuses they could enable. It is thus crucial to verify that UAV operations are compatible with international humanitarian law, privacy laws and normative principles.

Ethics in Research and Development Environments:

Aside from the ethical implications of UAV deployment, the ground situation also poses. The purchasing of the hardware for the project was facing issues with the system context. The components were purchased on AliExpress and
and delayed on custom for papers even approved by the university JLCPCB.
and local law enforcement. The officials attempted to squeeze bribes to let the parts pass. These procedures not only financially and emotionally exhausted the project (costing almost double its original budget), they also demonstrated systemic issues of corruption and institutional bungling within research infrastructure.

Such barriers undermine fairness, accessibility, and the spirit of academic inquiry. For emerging engineers and innovators in developing countries, these obstacles pose a significant ethical dilemma: whether to comply with corrupt demands or risk project failure. By formally reporting these issues and refusing to participate in unethical practices, this project aligns with the **IEEE Code of Ethics**, which emphasizes integrity, honesty, and responsibility in professional conduct.

5.2.4 Sustainability Plan

The design and operation of Kak and Kokil UAVs have the emphasis on sustainability. The plan focuses on reusing, using energy efficiently and using materials that are eco-friendly:

1. Reuse and Modularity.

i. Kak modular housing enables reversal of the engine, which increases the lifespan and saves on a variety of UAV platforms.

ii. Kokil is inexpensive, lightweight and intended not to be discarded but to be repaired and re-used.

2. Selection and Recycling of Material.

i. Carbon fiber and 3D-printed polymers have been selected because of their durability and recyclability.
ii. Electronic components are in accordance with the RoHS standards in order to reduce the hazardous wastes.

3. Energy Efficiency
i. Electric propulsion in the two UAVs lowers carbon emissions.
ii.The further reliance on fossil fuels can be reduced by future hybridization of solar-assisted charging stations.

4. Localized Supply Chain
i. The existing dependence on foreign vendors is both expensive and polluting.
ii. Far off, the aim is to create local fabrication laboratories in Bangladesh to lessen the effects of shipping.

5. End-of-Life Management
i. Batteries will comply with recycling guidelines of IEC 62133.
ii.Out of the structural materials, it is possible to recover and reuse them in new prototypes [16].

5.3 Project Management and Financial Analysis.

Budget (Kokil Prototype):
i Core build: ~$40-50 per unit.
ii Development overhead: ~$200-300.
iii Total prototype: ~$250-300

Alternate Budget & Rationale:
i Core build: ~$40-50 per unit.
ii Development overhead: ~$200-300.
iii Total prototype: ~$250-300

Budget (Kak Prototype):
* Estimated build: $2,800-4,000

1. **Alternate Budget & Rationale:**
   i If local PCB fabrication & open-source hardware sourcing were available, Kokil unit cost could drop below $35.
   ii Using off-the-shelf flight controllers instead of custom PCBs could raise costs but save time.
2. **Revenue Model:**
   i Military: low-cost tactical drones (Kokil) for reconnaissance.
   ii Civilian: agricultural monitoring, disaster response, and surveillance services.
   iii Commercial sale of Kokil in bulk as a "disposable" tactical drone [7].

5.4 Complex Engineering Problem

5.4.1 Complex Problem Solving

i **Problem:** Lack of nano-sized, lightweight flight controllers in Bangladesh; local PCB fabrication challenges.
ii **Solution:** Designed a custom PCB using KiCad + Flux AI simulation; fabricated via JLCPCB (China).
iii **Complexity:** Required integration of ESP32-S3, MPU6050, and MOSFET drivers within a compact, lightweight PCB design.
iv **Outcome:** Achieved functional stability, real-time free-fall detection, and motor spin-up, proving feasibility despite infrastructure barriers

5.4.1 Complex Engineering Problem

Table 5.1: Mapping with Complex Engineering Problem

Table 5.1: Mapping with Complex Engineering Problem.

EP1 Dept of Knowledge	EP2 Range Of Conflicting Requirements	EP3 Depth of Analysis	EP4 Familiarity of Issues	EP5 Extent of Applicable Codes	EP6 Extent Of Stake-holder Involvement	EP7 Interdependence
Integration of aerodynamics, hybrid propulsion, control (ESP32), and PCB design required multidisciplinary knowledge (K3–K6, K8).	Balancing endurance vs. agility, cost vs. performance, lightweight design vs. durability, and local vs. imported component sourcing.	Advanced modeling of flight dynamics, IMU sensor fusion, propulsion efficiency trade-offs, and custom PCB circuit validation using EDA tools.	UAVs often face stability, battery, and communication issues, but tackling hybrid propulsion and PCB fabrication in Bangladesh needed fresh, innovative solutions.	Compliance with IPC (PCB design), IEC 62133 (battery safety), IEEE 802.11/802.15.4 (communication), and IPC-A-610 (assembly).	Stakeholders included students, supervisors, local suppliers, international PCB manufacturers, and regulatory authorities (customs).	UAV subsystems (propulsion, flight controller, communication, frame) are highly interdependent; failure in one affects overall mission success.

Mapping with Knowledge Profile

This section maps the overall problem and **EP1** (requiring multiple knowledge areas between K3, K4, K5, K6, K8) to the **Knowledge Profile**.

Table 5.2: Mapping with Knowledge Profile

K1	K2	K3	K4	K5	K6	K7	K8

Natural Science	Mathematics	Engineering Fundamentals	Specialist Knowledge	Engineering Design	Engineering Practice	Comprehension	Research Literature
Applied physics (Newton's Laws, aerodynamics) guided UAV stability and thrust analysis.	Used in flight dynamics equations, PID tuning, and sensor fusion algorithms.	Electrical circuits, propulsion systems, and structural mechanics formed the foundation.	UAV topics like IMU integration, wireless standards, and hybrid propulsion.	CAD modeling, modular housing design, and payload integration.	PCB fabrication, soldering (IPC-A-610), and field testing under real conditions.	Understanding UAV impacts on privacy, environment, and disaster response.	Literature review of Shahed drones, Black Hornet Nano, and UAV propulsion technologies informed design.

5.4.2 Engineering Activities

This section maps the UAV project to **complex engineering activities (EA1–EA5)**.

Table 5.3: Mapping with Complex Engineering Activities

EA1 Range of resources	EA2 Level of Interaction	EA3 Innovation	EA4 Consequences for society and environment	EA5 Familiarity

Utilized diverse resources: simulation tools (Flux AI, KiCad), international PCB manufacturing, carbon fiber composites, and embedded microcontrollers.	Collaboration between hardware, software, and mechanical subsystems; also required interaction with suppliers, supervisors, and customs authorities.	Development of a custom nano flight controller, engine-swapping modular design for Kak, and throw-launch mechanism for Kokil.	Positive: disaster relief, agricultural monitoring, border security. Negative: privacy risks, emissions from jet propulsion. Mitigation: modularity, reusability, and electric propulsion.	UAV basics are familiar, but hybrid propulsion integration and systemic supply chain barriers in Bangladesh required novel, less familiar solutions.

5.5 Summary

The Kak and Kokil UAV project represents a **complex engineering problem** requiring multi-disciplinary knowledge, innovative design, and stakeholder involvement across local and international domains. The mapping above demonstrates alignment with established **complex engineering problem attributes (EPs), knowledge profiles (Ks), and complex engineering activities (EAs).**

Chapter 6

Conclusion

This chapter discusses what we have learned during this project, the challenges we encountered, and where we think this work is going. It summarizes our journey of creating and experimenting with Kak and Kokil — two UAVs that were initially just an idea on paper, but they became a working design driven by technical knowledge as well as ground-level problems.

6.1 Summary

With the help of this project, we aimed to design two complementary UAVs Kak, which is the long-range hybrid plane, and Kokil, which is the short-range tactical quadcopter. In the process, we integrated physics, electronics, aerodynamics and embedded system lessons to come up with working designs that were capable of balancing performance, cost, and adaptability.

Highlights were some of the following:

- i It is unusual to make an entirely built-in flight controller at this size scale.
- ii Investigating the idea of hybrid propulsion in Kak, by providing it with the flexibility to turn on and off a jet engine and an electric motor as required.
- iii The development of a modular design capable of deploying different payloads or even deploying Kokil during-mission.
- iv Demonstrating that a UAV such as Kokil can be constructed at as low as $45-50 per unit, mass deployment can be accomplished.

Simply put, the project was not a mere construction of drones, but it was also to demonstrate that innovation can be achieved even with minimal resources.

6.2 Limitations

- i Lack of Raw material sources
- ii Lack of a PCB fabrication workstation
- iii The Bangladesh Customs office is not very cooperative with this kind of project

6.3 Future Work

In the future we have a lot of opportunities: Carrying the full-scale testing of both Kak and Kokil in real missions, both disaster relief and border monitoring. Introducing AI-based autonomy such that the drones will be able to make smarter decisions in complex environments. Agreement on solar charging and other materials that are more environmentally friendly to minimize the environmental impact of UAVs. Varying the payload options, such as thermal cameras, LiDAR, etc, so that such drones can be beneficial to farmers, rescue workers, and even scientists. Above all, assisting in the creation of a local ecosystem in Bangladesh, small laboratories and workstations so that future engineers can design, produce, and test UAVs without the limitations that we have encountered. It has been more of a learning process than a creating process in this project. Although both Kak and Kokil are still in development phase, it is a sign of what is possible when drive, collaboration, and persistence are combined. Hopefully, future learners, investigators, and creators will build upon this base and bring UAV technology to a new level.

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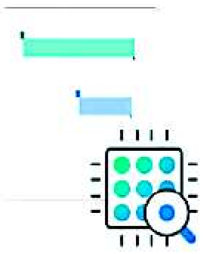

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