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Enhancing Autonomous Drones With Self-Designed Payload Droping Mechanism

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Abstract: This research paper provides a comprehensive exploration of an autonomous drone experiment integrating the Pixhawk 2.4.8 flight controller. The study offers a detailed analysis of a drone system characterized by a 200-gram payload capacity and a maximum flight duration of 13 minutes. The CAD model, meticulously designed using Dassault's SolidWorks Design Tool, incorporates carbon fiber propellers to optimize both durability and flexibility. One noteworthy contribution of this research is the introduction of a self-designed payload deployment mechanism, further extending the drone's capabilities. Additionally, specialized landing equipment is developed to enhance takeoff and landing stability, thereby elevating overall system performance. The study emphasizes the drone's precise control and navigation capabilities, made possible by its robust processing capacity and integrated sensors. Leveraging the computational prowess of the Raspberry Pi 4B, this project efficiently manages complex algorithms crucial for autonomous operations, all while maintaining cost-effectiveness. The Raspberry Pi's high-resolution capabilities and seamless integration prove to be the optimal choice for accurate object detection, environmental recognition, autonomous navigation, and successful payload deployment missions. This research contributes valuable insights into the integration of advanced technologies in autonomous drone systems, with a particular focus on enhancing their capabilities through self-designed payload deployment mechanisms.

Index Terms **- Drone, innovative design, CAD, FEA, payload mechanism.**

I. INTRODUCTION

Market for autonomous drones is estimated to be 15.5 billion USD by 2022, and with the development of artificial intelligence, the market is expected to grow evenfurther. In addition to the Military, many important sectors of industry require this technology,such as surveillance, delivery, etc. Future applications are creating a significant number of opportunities for the young aspirational generation of drone enthusiasts to undertake further research and discover a wide range of solutions. Start-ups aim to automate their services through autonomous drones, which sets them ahead of their competitors in terms of timing and results. In addition, achieving accuracy challenges industries to compete on a higher level.

II. INTEGRATED QUADCOPTER DESIGN

2.1. Conceptual Design

The Drone has been created and modelled using the finite element method, with a payload carrying capacity of 200 grams and an endurance duration of 13 minutes at a top speed. The mission's flying time was taken into consideration while choosing the UAV subsystems, which were created based on the literature on current UAVs and the drawing constraint frame.

- If we have a "+" configuration,
  The thrust forces are applied at distance = r.
- If you have an "x" configuration,

  The thrust forces are applied at a distance = r X cos (pi/4)

We can get about 41% more rotational acceleration from an "x" than a "+".

- X Configuration drone

$75^o + 75^o + 2x = 360^o$

$2x = 210^o$

$x = 105^o$

Now placing the distance between 2 motors

$AB^2 = AC^2 + BC^2 – 2AB\cos\gamma$

$AB^2 = (250)^2+(250)^2 – 2(250)(250)\cos75^o$

$AB^2 = 62500 + 62500 – 2(250)(250)0.2588$

$AB^2 = 125000 – 125000(0.2588)$

$AB^2 = 92650$

$AB = 304.39$

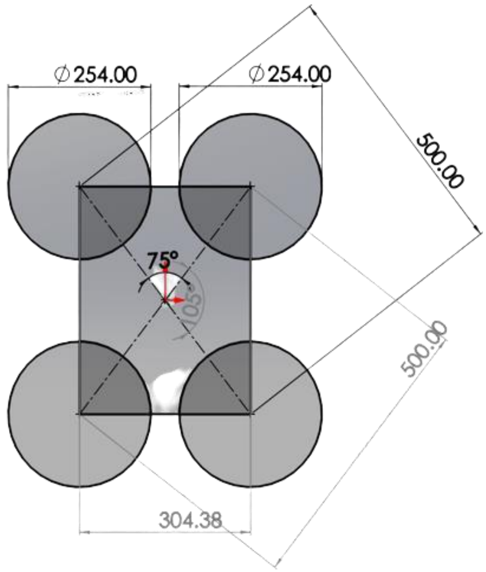


Fig 1: conceptual design

Now considering the diameter radius of the propeller 10 inches = 254 mm
The gap between the two propellers
= 304.38 – 254
= 50.38 mm
=5.038 cm
This ensures the feasible design of our drone.

2.2. Parametric CAD Model and Physical Parameters

In order to create the parametric CAD model, we used the SolidWorks design tool of the Dassault system. The final assembly is produced from the parametric design, which is carried out in a top-down manner. Overall, CAD model is an innovative design. Below are the isometric views and physical parameters for the Cad model.

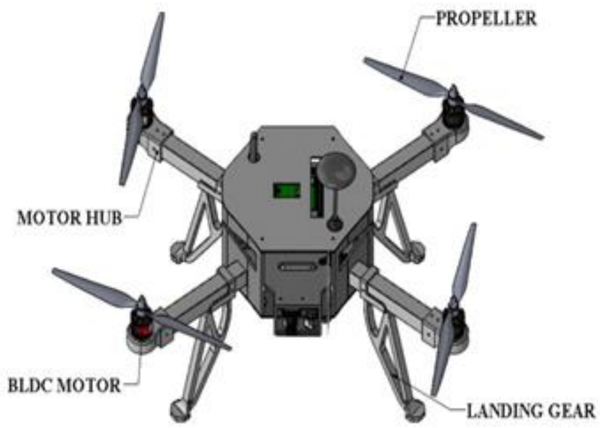


Fig 2: parametric CAD model of Drone

Table 1: physical parameters of CAD model

PARAMETERS	VALUES
DRONE WHEELBASE	500 mm
DRONE DIMENSIONS	396.68 X 304.38 X 283.64 mm
ARM LENGTH	180 mm
DRONE HEIGHT	209.5 mm
DRONE WEIGHT	633 If PLA USES
DRONE LANDING GEAR HEIGHT	130 mm
DRONE MOUNTING DIAMETER	38 mm
DRONE POWER SOURCE WEIGHT	959 mm
DRONE PROPELLER SIZE	10 x 4.7 inch

2.3. Drone Arm Selection (Design)

The drone arm is the critical component that provided structural support and houses the motor for propulsion. In this project, a square cross-sectional rod made of the carbon fiber material has been chosen as the arm design. The square rod has high bending strength is reason behind the choosing the drone arm and also the carbon fiber material offers excellent strength-to-weight ratio and durability, ensuring the strength integrity of the drone. The well compatible motor mounting system ensures secure attachment and optimal power transmission between the motor and the arm. Additionally, a carefully landing gear enhance the stability and safety of the drone during takeoff and landing, enhancing the overall performance of drone system.

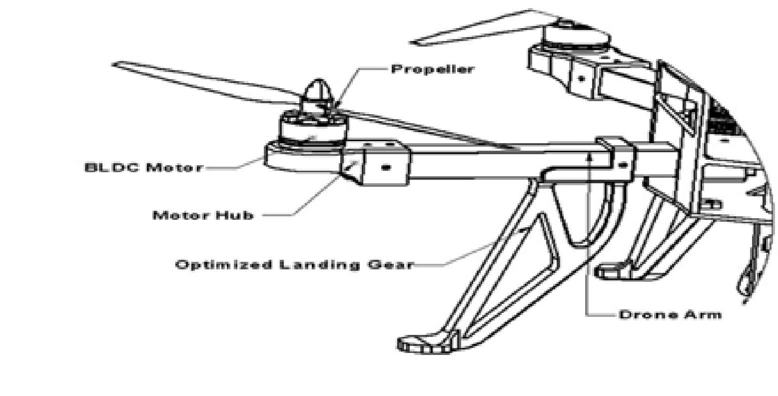


Fig 3: Drone arm

2.4. Object carrying and dropping mechanism

Our object carrying and dropping mechanism is comprised of a cage-like structure with sufficient volume to fit the moderate size of object. Now-a-days overall drone industry is working on the home delivery using the drone. For this point of view, we decided to design safe object delivering mechanism. Furthermore, we suggest that PLA be used to manufacture the payload-dropping mechanism, as it proves economical and able to sustain weights of approximately 200 grams object. An Mg995 servo motor is connected to a shaft which is used as the object-dropping mechanism. This allows the bottom lid of the cage to open in two halves, providing a freefall passage for the object to fall from the cage to the ground.

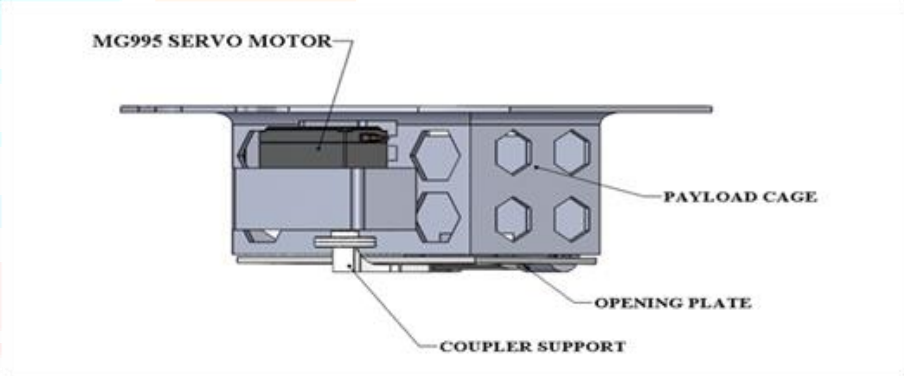


Fig 4: CAD of object carrying and dropping mechanism

2.5. Material selection

Carbon fiber is an incredibly durable material making the parts significantly more rigid. It has a superior adhesion layer that aids in creating objects of excellent quality. It also has lowweight, high resistance to chemicals, substantial tensile strength, and minimal thermal expansion. Also, by studying further more metallurgical properties of carbon fiber and theircomposites and analyzing the availability and cost cutting in the market we have derived this report.

Table 2: material properties of carbon fiber

Properties	PLA Carbon	PETG Carbon	Nylon Carbon
Tensile Strength	45.5 Mpa	56 Mpa	63.3 Mpa
Tensile Modulus	4950 Mpa	5230 Mpa	4387 Mpa
Elongation at break	2 %	2.4 %	4 %
Density	1.3 g/cm^3	1.317 g/cm^3	1.14 g/cm^3
Flexural strength	89 Mpa	80 Mpa	78 Mpa
Flexural Modulus	6320 Mpa	5740 Mpa	5650 Mpa
Glass TransitionTemperature	60	80	105

III. FINITE ELEMENT ANALYSIS

Finite element analysis is the most popular numerical method used to solve engineering problem. In this project we have done finite analysis of drone arm, landing gear and model analysis. For this analysis we have used Ansys software. The analysis is carried out in three step Preprocessing, Processing and Post processing.

3.1. Arm analysis

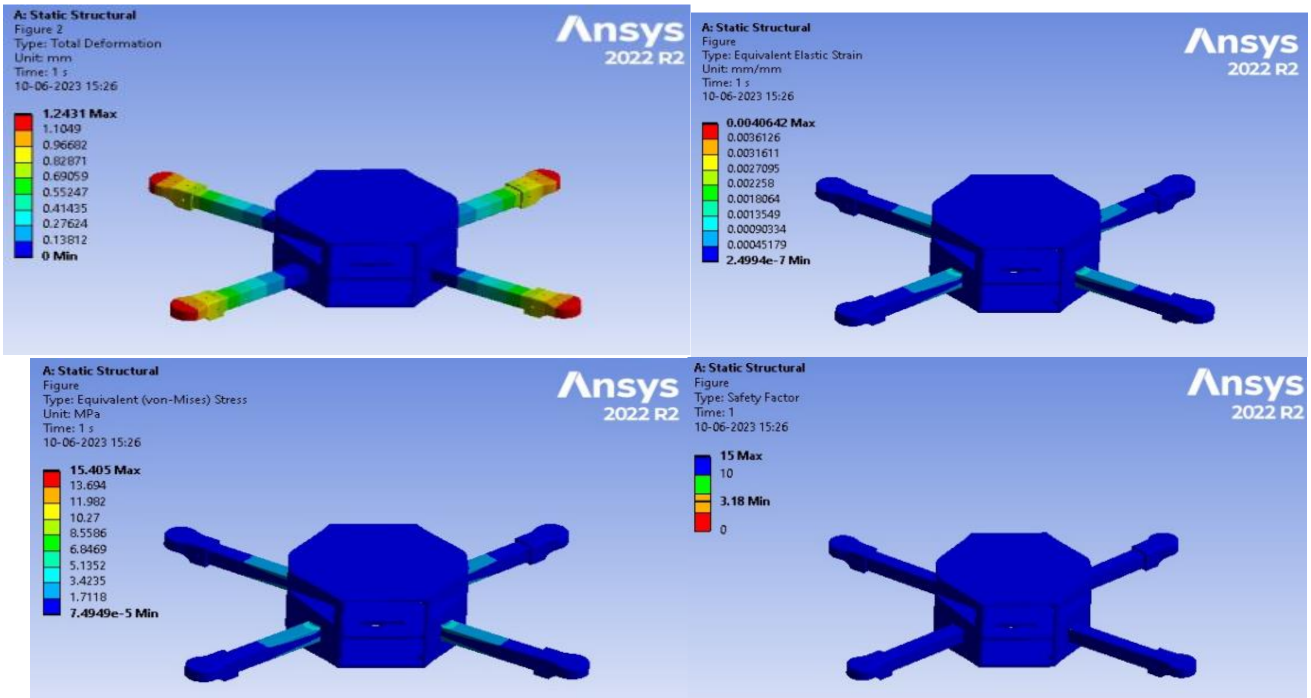


fig 5: Total Deformation, Equivalent(von-Mises) stresses and strain of drone arm analysis

TABLE 3: the physical parameters of structural analysis of arm

Parameters	**Values**
Ansys Model	2022 R2
Analysis Type	Static Structural (Vertical Loading Deformation)
Material Type	Carbon Fibre PLA
Statistics	
Elements	71935
Nodes	143518
Results	
Thrust Force	50N (Thrust Force)
Total Deformation	1.243 mm
Equivalent (von-Mises) Stress	15.405Mpa
Equivalent Elastic Strain	0.0040642
Factor Of Safety	3.18

3.2. Landing gear analysis

In this project, innovative landing gear design has been implemented. The conventional landing gear design typically consist of straight legs, providing minimal shock absorption capability. In below fig.no. 6 shows the structural analysis of the landing gear.

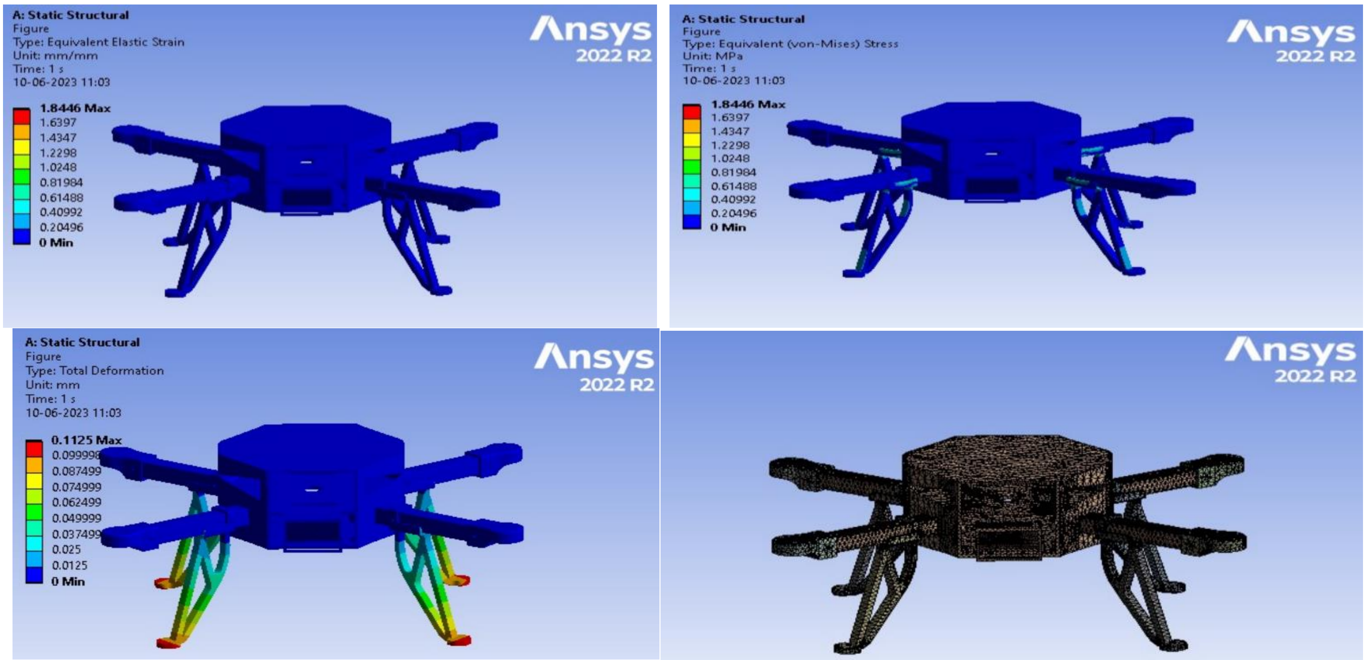


Fig 6: structural analysis of landing gear

table 4: physical parameters of structural analysis of landing gear

Parameters	Value
Ansys Model	2022 R2
Analysis Type	Static Structural (Drop analysis of Frame)
Material Type	Carbon Fibre PLA
Statistics	
Element Size	5.0mm
Elements	100141
Nodes	198455
Results	
Transverse Force	20N (On Impact side)
Total Deformation	0.1125 mm max
Equivalent (von-Mises) Stress	1.8446 Mpa

3.3. Modal analysis

IV. AVIONICS CALCULATION AND COMPONENT SELECTION

4.1. Propulsion system

- Factors to be Considered
  Weight of all components
  Propellers according to the frame
  Motors and Esc
  Battery and Estimate Flight Time

Thrust Estimation

Estimated drone weight = 1.8 kg = 1800gm

Thrust to weight ratio for payload transport drone must be at least **3**

Let "**x**" gm be the weight of the drone

Total weight = "**x+200**"gm

So, the thrust produced by each motor must be (x+200)/4 gm
X = 1800gm
Hence total weight = 2000gm
Thrust/weight ratio = 2.5
2.5 = Y/2000
Y = 2000*2.5
Y = 5000
Now thrust by each motor must be 5000/4 = 1250gm
= 12.50N

4.2. Component Selection

1) **Propeller** – Along with the above calculations the material of the propeller affects its performance on a large basis hence the material of the propeller is carbon fiber. The size of the propeller is 10*4.7 where 10 is the diameter and 4.7 is the pitch.

2) **Motor Selection** – To satisfy the thrust force to lift the drone the below motor is selected Generic EMAX GT2215-09 1180KV Outrunner Brushless Motor for RC Models. As per the testing table given in the motor manufacturing table, the thrust produced by the motor with 10*4.7 propeller satisfies our thrust to weight ratio.

No.Of cells	2-3xLi-Poly
Stator dimensions	22x15mm
Shaft diameter	4mm
Weight	70g/2. 46oz
Recomended model weight	300-1100g
Recomended prop without gearbox	10x4.7 11x3.8

Model	Cell Count	RPM/V	Prop (APC)	RPM	MAX current (<60S)	Thrust
GT2215/12	3S	905	10x4.7	7450	15A	1000g 2.20lb
	3S	905	11x3.8	7000	18A	1050g 2. 31lb
GT2215/09	3S	1180	10x4. 7	8300	26A	1250g 2. 76lb
	3S	1180	10x6	8850	24A	1140g 2. 51lb

3) **ESC selection** – The max current draw by the motor and propeller at highest thrust is 24 amp keeping safety margin of 40% we will be using ESC of 40A.

4) **Battery Selection**: The Time restriction for the mission completion is 10 min so as per the calculation battery of 5200 mah provides enough power to complete our mission so Orange 11.1V 5200mAh 45C 3S Hardcase Lithium Polymer Battery is used.

5) **Pixhawk 2.4.8**

The Pixhawk 2.4.8 flight controller was selected for its advanced capabilities and reliability in the autonomous drone project. Its robust computing power and integrated sensors enable precise control and navigation of the drone. Calculations involving floating numbers are performed using a floating-point unit (FPU), which leads to increase in accuracy. Its open-source nature allows for customization and the implementation of complex flight algorithms, ensuring stable and safe autonomous operations. When compared to other flight controllers available on the market with this range, it is both affordable and effective and easily available. Measure reason to choose this flight controller is to take stable autonomous flight which can be achieved with the help of its firmware mission planner. The Pixhawk 2.4.8's reputation and proven track record make it a preferred choice for achieving accurate and efficient flight control in our project.

Fig.7: Pixhawk 2.4.8

6) Raspberry Pi 4 Model B (8 GB RAM)

The selection of the Raspberry Pi 4B (8GB) module was driven by its powerful computing capabilities. With its enhanced processing power and memory capacity, the Raspberry Pi 4B can handle complex algorithms and tasks required for autonomous navigation and payload management. The module's extensive range of GPIO pins and connectivity options enables seamless integration with sensors and peripherals, contributing to precise and reliable drone operation. The Raspberry Pi can serve as an efficient companion computer by connecting to the Pixhawk via the mav-link Protocol, allowing for advanced onboard processing and decision-making capabilities, essential for executing complex autonomous operations with the Pixhawk-based drone at affordable price. The Raspberry Pi 4B's popularity and community support also provide access to a wealth of resources and potential for future enhancements in our project.

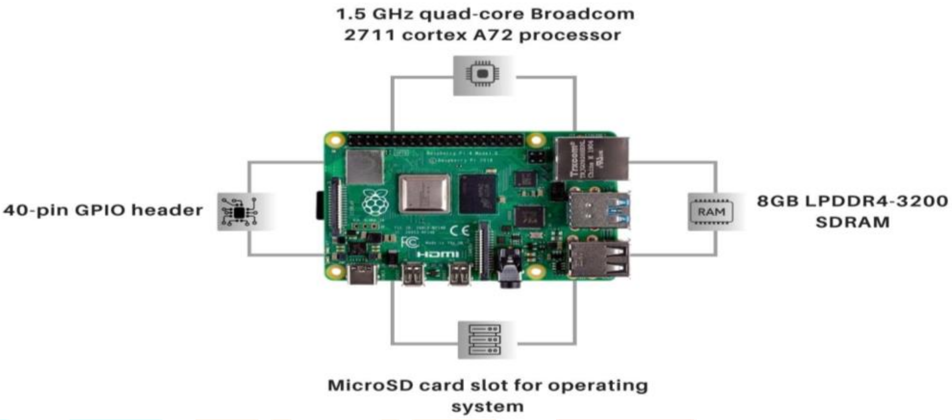


Fig.8: Raspberry Pi 4 Model B

7) Ardu-cam 8mp IMX 2199 camera

It is a compatible AI camera for Raspberry Pi with a Sony IMX219 sensor with a Maximum Resolution of 120 FPS @720 P or 60 FPS @1080p. Due to its high resolution and compatibility with the Raspberry Pi, it is the ideal choice for this project, enabling accurate object detection and environment perception for autonomous navigation.

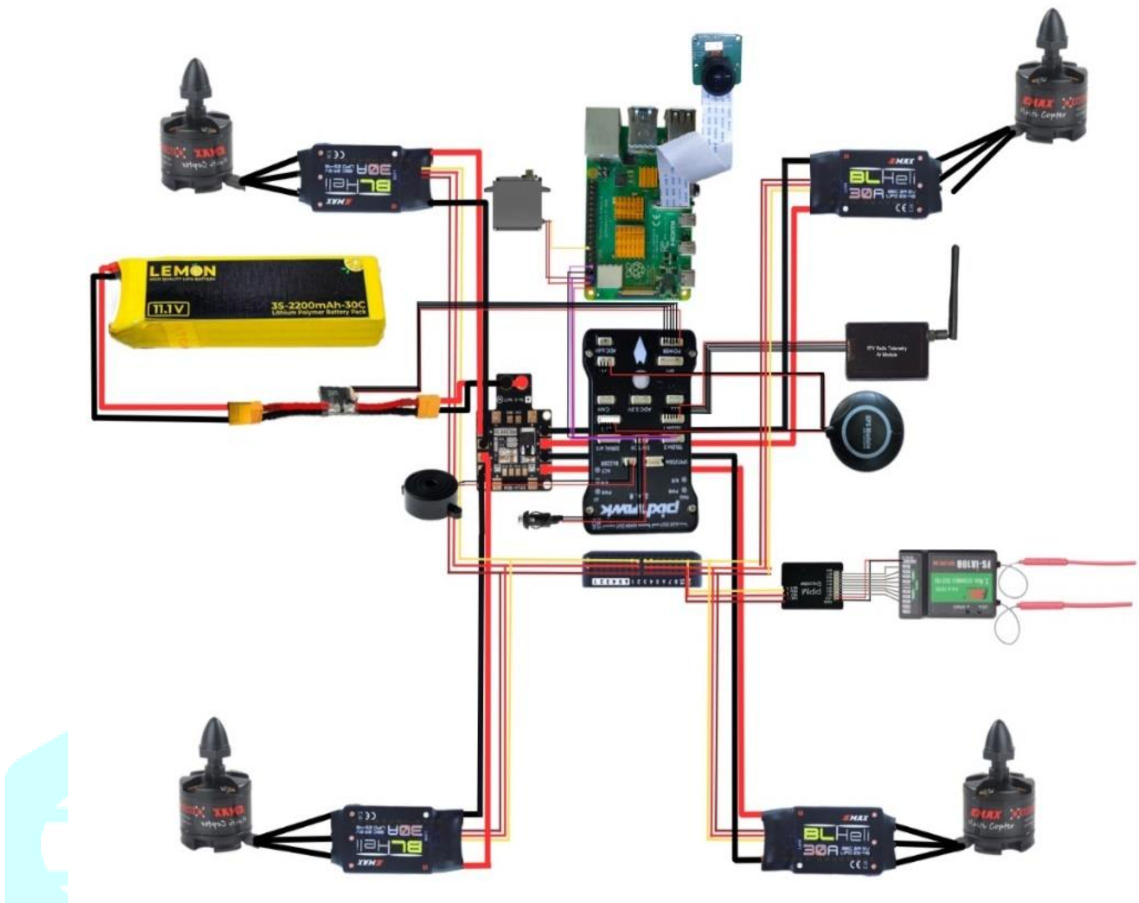
Fig.9: Arducam 8-MP IMX 219

8) Servo – Tower pro MG 90s

Servo Motor is used in the Payload drop mechanism which can be controlled by the Raspberry Pi autonomously.

Tower Pro Mg90s is a micro servo with an operating voltage of 4.4-6.6V with a torque of 1.8 – 2.2 kg-cm respective to its voltage.

4.3. Electronic Block diagram



V. CONCLUSION

In conclusion, this research has explored autonomous drone technology, specifically focusing on integrating the Pixhawk 2.4.8 flight controller. Our study featured a drone with a 200-gram payload capacity and a 13-minute maximum flight duration, showcasing its adaptability.

A significant contribution is the custom payload droping mechanism, broadening the drone's potential applications. The use of carbon fiber propellers and SolidWorks for CAD design highlighted the importance of material and design choices in optimizing performance.

Additionally, specialized landing equipment improved stability, driven by the Raspberry Pi 4B's computational power for autonomous operations. This research advances our understanding of enhancing autonomous drones, setting a standard for future developments across industries and applications in a concise format.

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