ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr2168

Design and Development of a Micro Drone to Enhance Rescue Missions in Fire-Affected Zones

Tamil Selvan S[1]; Kamalesh C[2]; Mohamed Thasthick S[3]; Rohith Ganesh G[4]; Saravana C[5]

[1]Assistant Professor,Department of Aeronautical Engineering ,Hindusthan Institute of Technology, Coimbatore, Tamil Nadu , India
[2,3,4,5] UG Scholar, Department of Aeronautical Engineering, Hindusthan Institute of Technology, Coimbatore, Tamil Nadu.

Publication Date: 2025/05/13

Abstract: Firefighting operations under risky conditions expose crews to risks such as heat and poor visibility. This project is focused on developing and manufacturing a micro drone to enhance rescue effectiveness by navigating congested spaces and making real-time observation. The development process consists of aerodynamic modelling in SolidWorks to ensure stability and maneuverability, and functionality is enhanced by using high-performance materials, sensors, and optical systems. Accuracy is achieved in manufacturing by vertical tower milling to produce accurate parts. The flight time and obstacle avoidance are tested on the prototype.

Keywords: *Fire Rescue, Micro Drone, Poor Visibility, Hazardous, Solid Works, and Vertical Tower Milling.*

How to Cite: Tamil Selvan S; Kamalesh C; Mohamed Thasthick S; Rohith Ganesh G; Saravana C (2025) Design and Development of a Micro Drone to Enhance Rescue Missions in Fire-Affected Zones *International Journal of Innovative Science and Research Technology*, 10(4), 3423-3429. https://doi.org/10.38124/ijisrt/25apr2168

I. INTRODUCTION

Fires in urban and industrial areas have increasingly challenged rescue operations, exposing personnel to high temperatures, dense smoke, and poor visibility. Traditional methods, while effective, carry significant risks. Integrating modern technology can reduce these dangers and improve the overall efficiency of rescue missions.

This project focuses on the design and development of a micro drone specifically for fire-stricken areas. Built with lightweight materials like carbon fibre and aluminium, the drone is compact, agile, and capable of navigating confined, hazardous spaces. It features thermal imaging to detect human presence through smoke and debris, and electronics designed to withstand high temperatures for short periods. By providing real-time visual and thermal data to rescue teams, the drone enhances situational awareness and speeds up the identification of trapped individuals, bridging the gap between firefighting operations and advanced drone technology.

➢ *Micro Drone*

A micro drone is a light and small unmanned aerial vehicle for use in confined or difficult-to-reach spaces. Our drone is approximately 2 kilograms in weight and has a flight controller, high-torque motors, and a camera to take live video or photos. It has excellent stability in flight and can undertake work like tracking people in areas of fires that are hazy.

With a flight duration of approximately 15 minutes, the drone is able to traverse lengthy areas in rescue operations without constant recharging. The design of the drone provides durability with a compromise between weight and strength so that it is perfect for missions that are sensitive in nature and need agility and rapid responses in harsh environments.

II. LITERATURE SURVEY

Sreeramoju & Sreenivasa Rao (2023)"Design and Analysis of Quad Copter Chassis Using Shape Optimization Technique" describes the use of shape optimization in SolidWorks to reduce UAV frame structures to achieve maximum strength and minimum weight. By metal and carbon material comparison and topology optimization, the authors minimized frame weight by 35.88% (85.06 g to 54.54 g)—over the target of 30%—with Factor of Safety as 6.39 (compared to 3 conventional) and Von Mises stress of 3.13 MPa. Optimized chassis improves flight efficiency, endurance, and payload for quadcopters. Akhloufi, Couturier & Castro (2021)"Unmanned Aerial Vehicles for Wildland Fires: Sensing, Perception, Cooperation and Assistance" overviews UAVfire detection and response platforms. It cites limitations of satellites and WSNs in wildfire monitoring in real time and how UAVs—instrumented with thermal

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr2168

sensors, LiDAR, and AI-based navigation—are adaptive, economical platforms for early detection and awareness of the situation. The paper also explores cooperative UAV-UGV frameworks, deep-learning advances, and challenges in flight duration and decision-making autonomy for large-scale disaster management. Tang et al. (2019)"Preparation and Properties of Lightweight Carbon/Carbon Fiber Composite Thermal Field Insulation Materials" presents a needle-punching-forming-felt process to fabricate low-density (0.16 ± 0.02 g/cm³) carbon/carbon fibre composites with three-dimensional X-Y-Z fiber networks. The composites provide superior thermal insulation (0.38 W/m·K at 2000 °C), extremely low impurity concentration (19.09 ppm), and high structural strength at severe temperatures and thus are best suited for use within high-temperature furnaces. Gelfert (2023)"A Sensor Review for Human Detection with Robotic Systems in Regular and Smoky Environments" explores single- and multi-sensor approaches to victim detection in smokeladen environments. It categorizes technologies—thermal cameras, LiDAR, radar, optical imaging, and sensor fusion with AI—and mandates segmentation algorithms, deep learning models (e.g., YOLO, SSD), and operator robot communication problems. The review identifies potential areas for future improvement in sensor accuracy, multi sensor coordination, and search and rescue autonomy of robots. Jiang, Y., et al. (2020)"Drones in Firefighting: Applications and Advances "This paper discusses the application of drones in dangerous fire fighting, addressing the issue of low visibility and the provision of real-time information". The authors highlight the application of real-time aerial perception through high-definition cameras, thermal sensing to detect heat signatures in contrast to the smoke background, and path-autonomous flight in navigating unsafe environments. The drones also allow for real-time communication with ground forces. The abstract points out that drones improve the safety and operational effectiveness of firefighters significantly but nonetheless, there is room for improvement in endurance, thermal protection, and system integration. Liu, H., et al. (2019)Title:"IEEE Transactions on Emergency Services"The article explains using thermal cameras on drones for enhanced victim detection in smoky conditions. With infrared detectors and image-recognizing algorithms, the drones are able to identify human targets in the smoky, fire-simulated zones. The research shows how heat-assisted drones enhance the rescue mission even further, although through further work on maneuverability and image processing to offer enhanced performance in adverse conditions.Kim, J., et al. (2021)"Structural Design for Rescue Drones" The text is dedicated to the drone design to fly in dangerous fire environments and the challenge of lightweight construction that is tough and heat-resistant. The authors research materials such as carbon fiber and aluminium alloys and conduct various frame designs (octocopter vs. quad-copter) for stability and flight characteristics. The research concludes that carbon fiber and an octagonal frame provide the optimal strength-to-weight ratio, as well as toughness, while heat insulation is most important where there are fire zones in order to safeguard electronics in drones. Johnson, T. (2021)"Navigational Challenges for Drones in Fire Situations "The paper describes malfunctioning of GPS and visual sensors because of smoke and debris and subsequent drone collisions. The research suggests infrared and thermal sensors to detect obstacles and IMU and GPS fusion for stability. Obstacle avoidance algorithms are also suggested to navigate through narrow spaces. The conclusion suggests that sophisticated sensor fusion and flight algorithms be developed for autonomous firefighting in dynamic fire environments. Robinson, P. (2022)"Emergency Services Review"This article offers case studies of the employment of drones equipped with thermal sensors, GPS, and obstacle sensors to conduct search and rescue operations in wildfires, floods, and earthquakes. The research provides that drones speed up search-and-rescue (SAR) operations at very little risk to personnel. The article proposes additional battery life, communication technology, and navigation systems to improve the efficiency of SAR further. Smith, A., Kumar, P., & Lee, J. (2022) "LiDAR-Enhanced UAV Navigation for Indoor Search and Rescue "The topic of this paper is utilizing LiDAR technology on the UAV during building search and rescue missions in scenarios where there is no GPS signal present. 16-beam LiDAR and IMU are combined SLAM-fused to aid dynamic path planning and smoke avoidance. The outcome indicates that this blend achieves ±10 cm localization precision and minimizes collisions by 85% in simulated smoke environments, demonstrating the viability of LiDAR-assisted navigation for indoor SAR missions. Gupta, R., Chen, S., & Alvarez, M. (2020)"Multi-Sensor Fusion for Improved Firefighting UAVs "The paper presents the merits and demerits of using single-sensor systems on fire-fighting drones and suggests a multi-sensor suite of RGB, thermal, CO_2, and gas sensors. Data is combined with an Extended Kalman Filter, and the result is displayed on a 3D UI overlay, which highlights hotspots, gas leaks, and victims. The research discovers that the multi-sensor system improves hazard detection by 30% compared to thermal-only systems, enabling improved decision-making in advanced fire scenarios. Singh, V., Patel, R., & Thompson, L. (2023)"Modular Drone Architecture for Rapid Emergency Response "This paper presents a modular drone platform that can be rapidly reconfigured to emergency response missions. The system is tray-based with hot-swappable payload modules (camera, LiDAR, speaker, etc.), which facilitates rapid role switching. Modular design saves 75% of the reconfiguration time, thereby enabling the same UAV to be configured in roles in minutes, thereby making it suitable for dynamic emergency response. Chen, Y., Zhang, H., & Roberts, T. (2020) "Battery Management Systems for Extended UAV Rescue Missions"This research solves the thermal runaway and short endurance problem of high-discharge LiPo batteries in rescue UAVs. The authors design a BMS for cell-level health, power balancing, and over-temp shut-offs. They implement AI predictive ETA based on throttle usage and environment to achieve an extension of 20% in safe flight time and 90% reduction of surprise landings.

III. METHODOLOGY

➢ *Problem Statement*

- *Close Proximity To Firefighters:*

Firefighters are under close proximity in dangerous conditions, like fire-damaged buildings, where death or injury is a strong probability due to low visibility and intense heat.

- *Finite Vision In Fire Areas:*

  Visibility is drastically lessened by fire and smoke, which is difficult for rescue squads to see through and find trapped victims rapidly and effectively.

- *Lack Of Drone Solutions For Harsh Environments:*

  The existing drones are not capable of flying in the hostile environment of fire areas and hence cannot be used for rescue operations or to feed real-time information.

- *Dual Drone Sophistication:*

  Maintaining two drones for rescue and firefighting missions complicates the rescue operations with a more combined solution where the two capabilities are integrated in a single adaptive drone.

➢ Objective

The goal of the principal objective of this study is to develop a micro drone for search and rescue within fire-affected areas. The drone will provide real-time feedback to aid identification of trapped victims. The concept will include durability and flexibility, with parts able to withstand hot temperatures and bad visibility, hence enhancing situational awareness and rescue team decision-making during adverse environments.

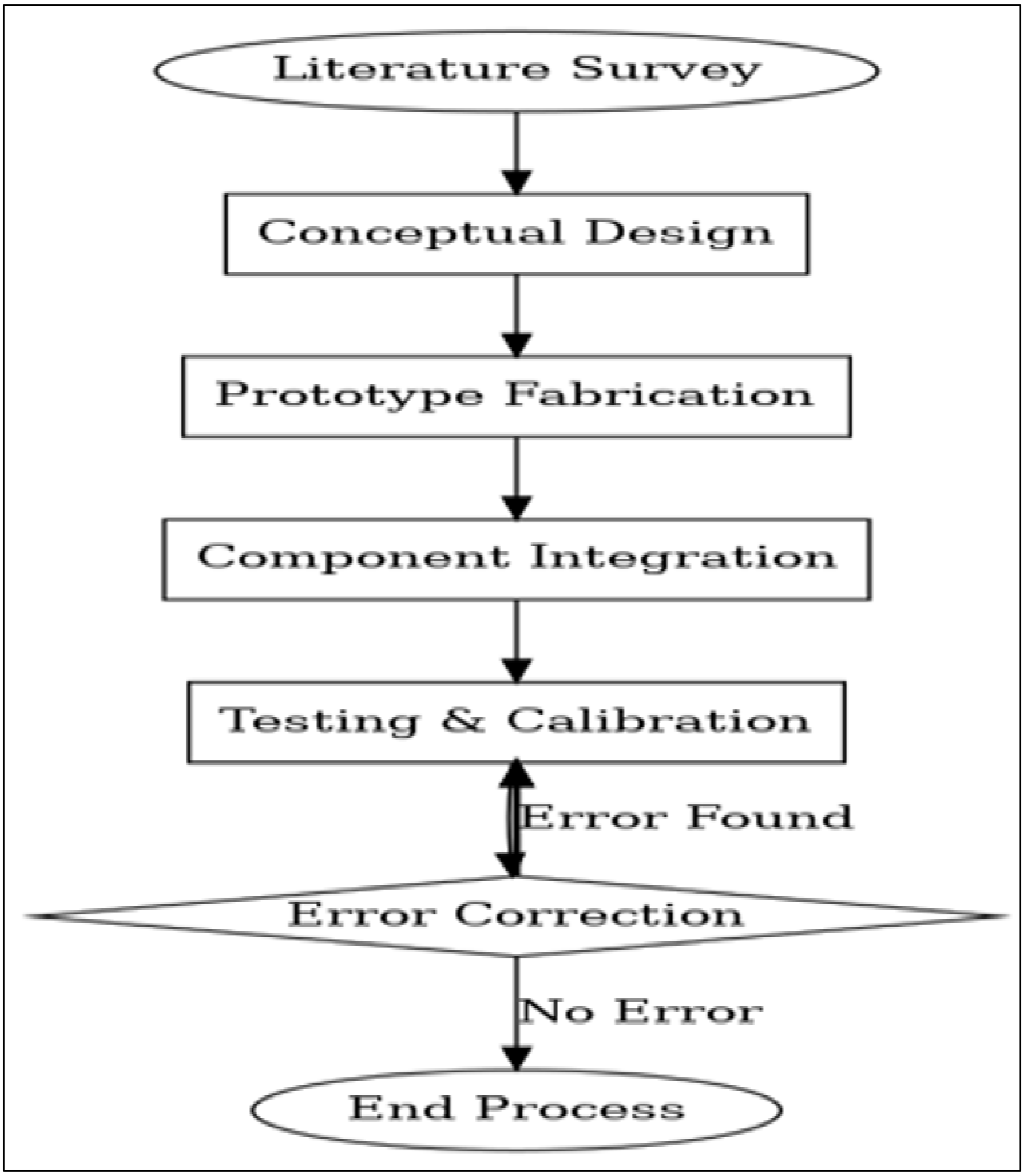

Fig 1 Work Process

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr2168

➢ *Procedure:*

Micro drone design for rescue in fire-affected regions is a systematic design process, component selection, fabrication, integration, and testing. It starts with conceptual design and requirement analysis where problems of fire rescue missions are addressed and major requirements such as thermal tolerance, navigation attribute, and miniaturization are established. A light-weight but thermal-tolerant structure is selected due to its reliability.

The second is the use of heat-resistant materials in the arms and frame, motors, ESCs, flight controllers, and endurance and stability batteries. A thermal imaging camera (Seek Thermal Compact) and LiDAR are mounted to locate victims and navigate, and LED lights are installed for smoke-sight visibility.

In production, there is a unique carbon fiber frame and aluminum legs, together with a unique battery compartment for improved weight balance. The other electronic parts like flight controller, ESC, motors, and sensors are then fitted.

Integration calibration and software include the process of installing safe flight by calibrating the flight controller to accommodate flight stability as well as the continuous integration of thermal image and LiDAR data to assist in detecting obstacles and identifying victims. Ground tests for efficiency in motor usage, accuracy in sensors, and stability complete the testing and validation process before testing outdoor and indoor application as well as flight and maneuverability checks in close spaces.

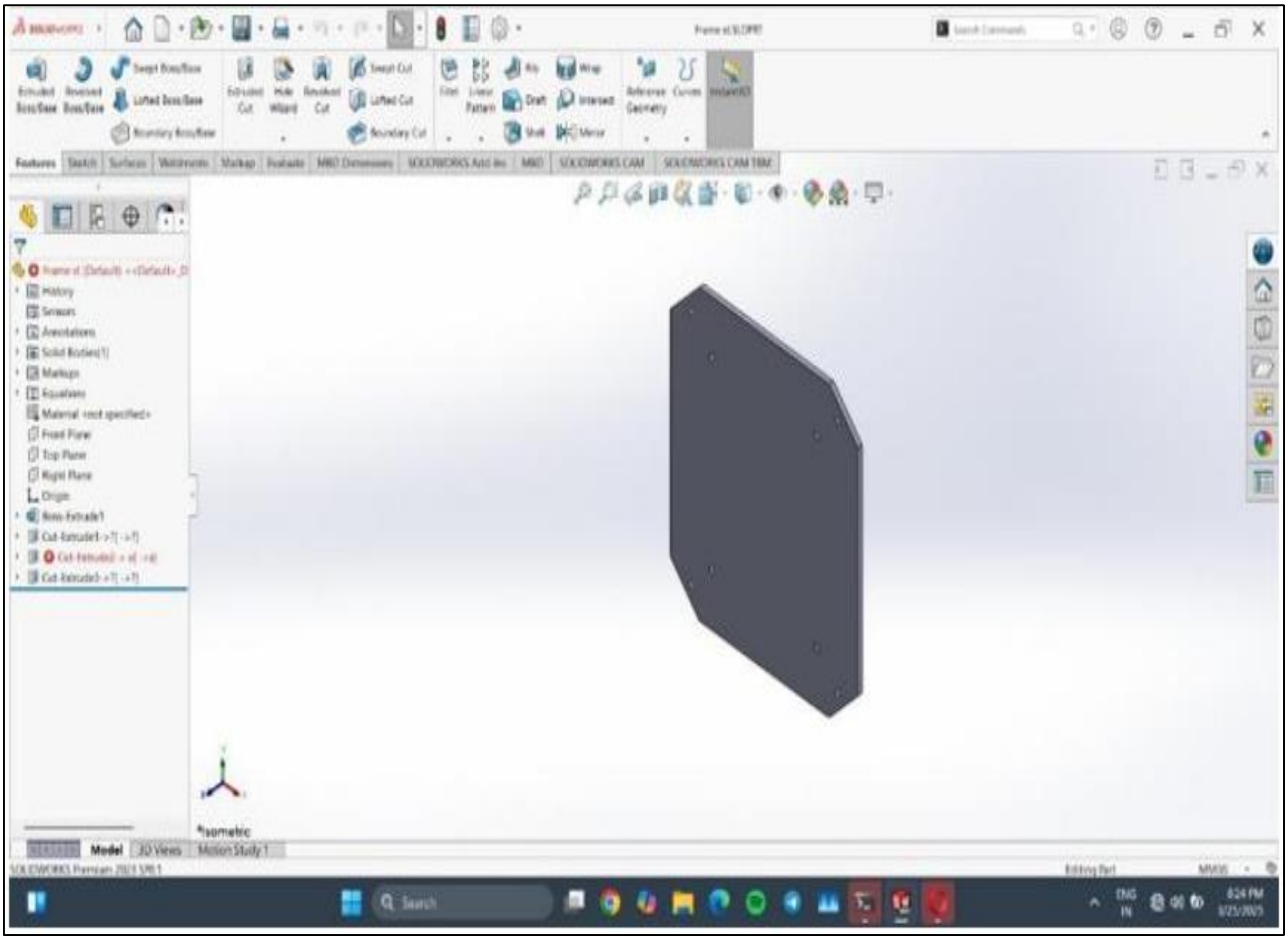

Fig 2 Base Plate (Carbon Fiber)

The above Figure shows the 115mm x 135mm carbon fiber base plate, which was used because of its strength-to-weight ratio, heat tolerance, and durability. It serves as the platform for mounting main components, enabling optimal weight distribution and stability during flight.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr2168

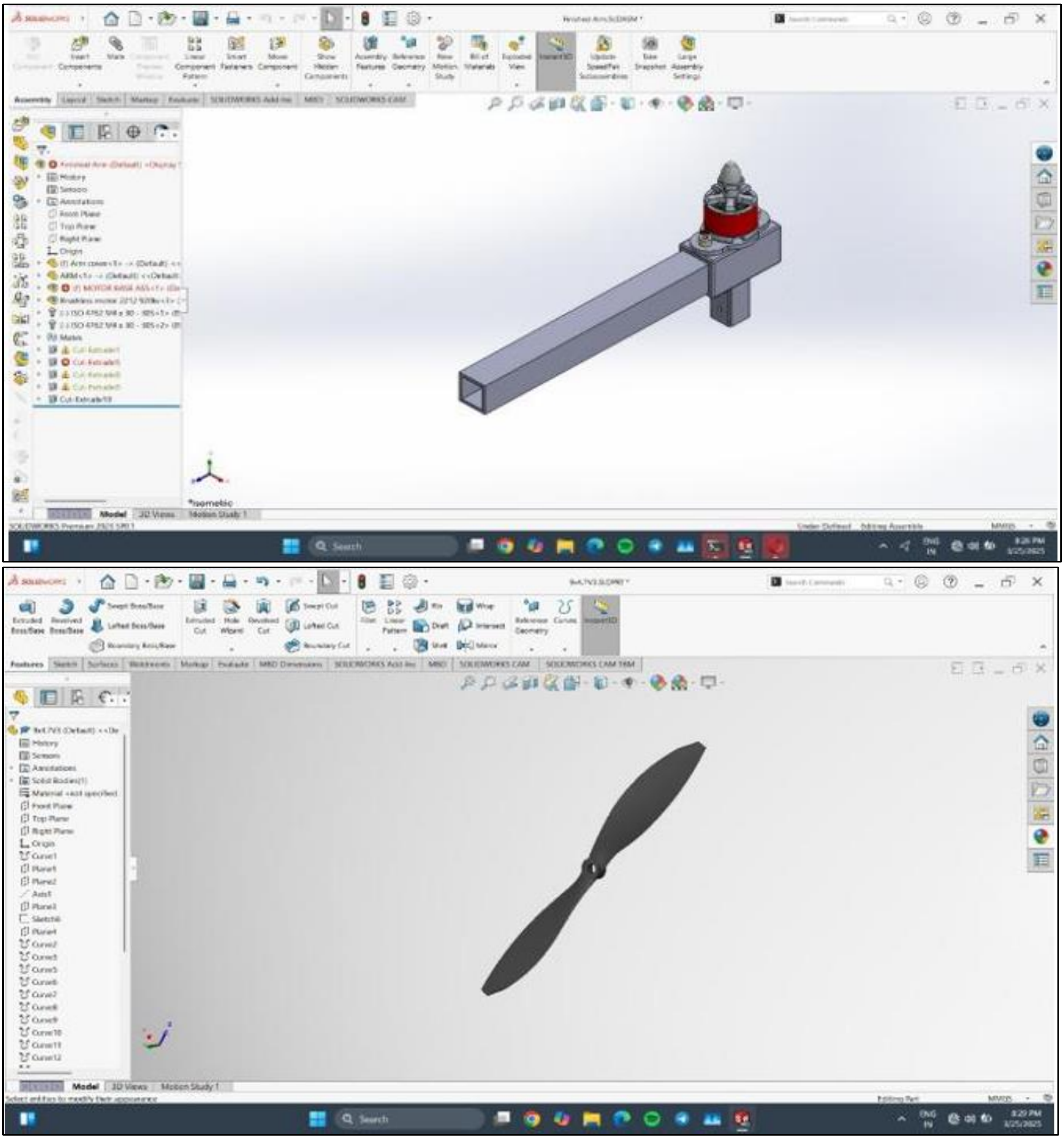

Fig 3 Aluminum Arm and Propeller

The above Figure depicts the Aluminum Arm and 10×4.5 inch propeller with a diameter of 10 inches and pitch of 4.5 inches, providing efficiency and thrust balance for smooth rescue flight. It is constructed using light but strong material to provide uniform performance and minimum vibrations.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25apr2168

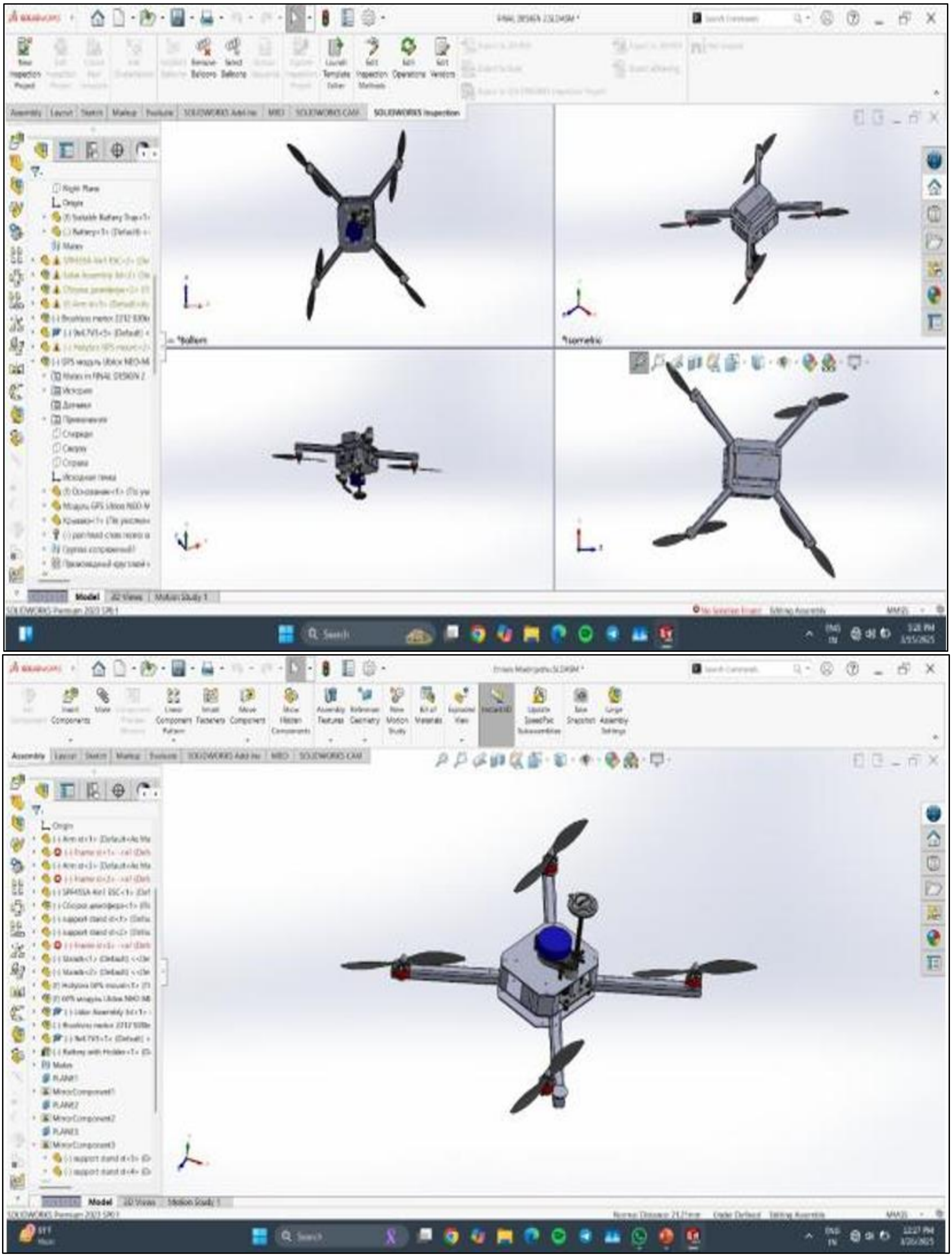

Fig 4 Full Design of the Drone

The Above figure shows the 2-axis gimbal mounted on the drone to stabilize the onboard camera system. This gimbal provides tilt and roll stabilization, allowing the camera to maintain a steady orientation despite the drone's movement during flight. It effectively reduces vibrations and minor disturbances, ensuring clear and stable thermal or visual imaging. The 2-axis configuration is lightweight and energy-efficient, making it ideal for micro drones used in rescue operations where stable footage is essential for identifying trapped individuals or navigating through smoke-filled environments.

IV. RESULTS AND DISCUSSION

➢ *Results*

The carbon fiber and aluminum light micro drone ensured heat resistance and structural stability. Indoor flight tests with controlled flight demonstrated consistent hovering and quick translation in extremely limited spaces. Real-time thermal imaging was ensured by the Seek Thermal Compact camera, attached to a handheld device, and Skydroid FPV and the thermal module during static and dynamic flight conditions. The quadcopter flew for 8–10 minutes on a battery pack of 4200mAh LiPo, where ReadyToSky 2212 motors and carbon fiber propellers provided a >1 thrust-to-weight ratio. Heat resistance tests proved the capability of the material to resist high temperature, and the electronic components remained well within typical readings up to 60°C. The thrust meter tested the motor-propeller combination efficiency at different RPM.

➢ *Discussion*

The UAV performed well in building environments, showing promise to aid rescue teams in heat detection and piercing tight spaces. Its light frame and heavy thrust motor offered compromise between flight time and payload carrying capacity. Operations in harsh fire environments need further improvement, possibly with the addition of shielding or cooling. Image sharpness was affected to some degree by flight vibration, which could be resolved using soft mounts or image stabilization software. While actual real-time delays were negligible, low latency in high-interference environments remains an issue. Development in the future could include enhancing the stability and communications systems of the drone to function better in challenging environments.

V. CONCLUSION

The design and development of the rescue micro-drone for burned fire areas have been successfully established, aiming to have a light-weight temperature-capable platform with Pixhawk flight control, BLDC motors, and LiPo battery. The drone was able to have consistent operation with ground and flight testing, having been effective in the simulations of low-visibility tests. Carbon fiber and aluminum use helped with the reduction of vibrations and added stability to provide accurate feedback. Autonomous flight, remote observation, and live streaming to handheld phones further demonstrated its use for rescue teams working within hazardous environments. This project creates the groundwork for future expansion, including LiDAR integration, and is an enormous leap ahead for aerial vehicles in rescue applications.

REFERENCES

[1]. Jiang, Y., et al. (2020). "Drones in Firefighting: Applications and Advances." Fire Technology.
[2]. Johnson, T. (2021). "Navigational Challenges for Drones in Fire Situations." Journal of Navigation.
[3]. Kim, J., et al. (2021). "Structural Design for Rescue Drones." Journal of Aeronautics.
[4]. Liu, H., et al. (2019). "Thermal Imaging Applications for Firefighters." IEEE Transactions on Emergency Services.
[5]. Chen, Y., Zhang, H., & Roberts, T. (2020). Battery Management Systems forProlonged UAV Rescue Missions.
[6]. Gupta, R., Chen, S., & Alvarez, M. (2020). Multi-Sensor Fusion for Enhanced Firefighting UAVs.
[7]. Jiang, Y., et al. (2020). Drones in Firefighting: Applications and Advances. Fire Technology.
[8]. Johnson, T. (2021). Navigational Challenges for Drones in Fire Situations. Journal of Navigation.
[9]. Kim, J., et al. (2021). Structural Design for Rescue Drones. Journal of Aeronautics.
[10]. Liu, H., et al. (2019). IEEE Transactions on Emergency Services.
[11]. Lopez, M., Nguyen, A., & Davies, K. (2019). Swarm UAV Systems for Wildfire Monitoring and Suppression.
[12]. Patel, S., Huang, Z., & Kim, D. (2022). Advanced Communication Protocols for UAVs in High-Interference Environments.