

# Real-Time Multi-Sensing Robotic Platform with Wireless Video Surveillance

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**Abstract**— With the increasing need for safety in military, defense, and hazardous environments, intelligent robotic systems have become essential to reduce human risk. This paper presents the design and implementation of a multi-functional IoT-based robotic system integrated with a robotic arm for bomb and metal disposal operations. The proposed system is built around an ESP32 microcontroller, which controls multiple sensors and actuators for real-time monitoring and decision-making. The robot is equipped with metal detection, LPG gas sensing, temperature and humidity monitoring, RFID identification, and wireless video surveillance using an IP camera. A robotic arm mechanism is integrated to safely pick and dispose of suspicious metallic or explosive objects, minimizing human involvement in dangerous situations. The movement of the robot is controlled through motor driver modules, while live video streaming enables remote monitoring and navigation. The system also supports wireless communication for real-time data transmission and control. The inclusion of an intelligent gripping arm enhances the robot's capability to handle bomb-like objects safely and efficiently. Experimental results demonstrate that the proposed system provides reliable sensing, stable movement, and effective object handling, making it suitable for military surveillance, bomb disposal, border security, and disaster management applications. This low-cost, scalable, and energy-efficient robotic platform offers a practical solution for modern defense and safety operations, reducing human risk while improving operational efficiency

**Keywords**— *IoT-based Military Robot, Bomb Detection and Disposal, Robotic Arm, Surveillance System, Wireless Control, Sensor Fusion, Autonomous Navigation, Real-Time Monitoring, Embedded Systems, Defense Robotics etc.,*

## I. INTRODUCTION

The rapid advancement of Internet of Things (IoT) and embedded systems has significantly transformed modern military and surveillance operations. Traditional military reconnaissance and bomb disposal missions involve high risk to human life due to hostile environments, unexploded ordnance, and limited visibility. To overcome these challenges, researchers have increasingly focused on developing IoT-enabled robotic systems capable of performing surveillance, monitoring, and explosive handling tasks remotely. Recent studies have demonstrated the effectiveness of IoT-based robotic platforms in military applications such as surveillance, border monitoring, and object detection. Sirisha Devi et al. [1] proposed an IoT-based military robot capable of real-time monitoring and wireless control, improving battlefield awareness. Similarly, Arjun et al. [3]

developed a multifunctional robot that integrates sensors and wireless communication for military reconnaissance. Ravikiran et al. [4] emphasized the importance of smart surveillance robots using IoT for real-time video transmission and obstacle detection. With the advancement of sensor fusion and intelligent control, modern robotic systems are now capable of detecting metals, capturing live video, and transmitting environmental data. However, most existing systems lack an effective mechanism for safe bomb handling and disposal. Recent studies have highlighted the importance of robotic arms for explosive handling to minimize human involvement in hazardous operations [13–15]. The integration of robotic arms with IoT-based mobile platforms offers a promising solution for real-time bomb detection, identification, and disposal. Therefore, this project focuses on developing a multi-functional IoT-based military robot integrated with a robotic arm for bomb disposal, real-time surveillance, and wireless control. The system aims to enhance safety, operational efficiency, and situational awareness in defense and security applications.

The remainder of this paper is organized as follows. Section 2 presents a comprehensive

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literature survey discussing existing IoT-based military robots, surveillance systems, and bomb detection technologies, highlighting their methodologies and limitations. Section 3 describes the proposed multi-functional robotic system in detail, including hardware architecture, working principle, and the integration of the robotic arm for bomb disposal. Section 4 discusses the experimental results and performance analysis of the developed system in terms of functionality, reliability, and real-time operation. Finally, Section 5 concludes the paper with key findings and outlines the future scope of the proposed system for advanced defense and security applications.

## II. LITERATURE SURVEY

Recent advancements in robotics and the Internet of Things (IoT) have significantly contributed to the development of intelligent systems for military and surveillance applications. In high-risk environments such as bomb detection, border surveillance, and reconnaissance missions, human involvement is highly dangerous. Hence, researchers have focused on designing autonomous and semi-autonomous robotic systems integrated with sensors, wireless communication, and real-time monitoring capabilities. Ch.S.N. Sirisha Devi et al. [1] proposed an advanced IoT-based robot designed for military operations such as surveillance and remote monitoring. The system utilized wireless communication and sensors to transmit real-time data to a control station. Although the robot improved situational awareness, it lacked object manipulation capability and bomb-handling mechanisms, which are crucial for defense operations. M. T. et al. [2] introduced an energy-efficient IoT-enabled flying robot for agricultural field monitoring. Their work focused on smart sensor integration, power optimization, and remote monitoring using IoT platforms. While the approach demonstrated efficient energy utilization and automation, it was limited to aerial monitoring and did not address ground-level threats or explosive handling. Arjun B. and Dr. Suresh D. [3] developed a multifunctional military robot capable of surveillance and obstacle detection using IoT technologies. Their system supported live video streaming and remote navigation, improving battlefield awareness. However, the model did not include an active robotic arm or bomb disposal mechanism, limiting its application in explosive

handling scenarios. K. Ravikiran et al. [4] proposed a smart surveillance robot using IoT for military environments. The robot was equipped with sensors and wireless transmission modules to detect intrusions and monitor surroundings. Although effective for surveillance, the system lacked autonomous decision-making and physical object manipulation features such as gripping or disposal units. Govindaraj et al. [5] presented an IoT-based patient monitoring system using deep learning for health prediction. Though focused on healthcare, the study demonstrated efficient real-time data acquisition, sensor fusion, and cloud-based analysis, which are applicable to military robots for health monitoring of soldiers and system diagnostics. Abdul Qadir et al. [6] designed an IoT-based military robot capable of remote navigation and surveillance. Their work emphasized real-time video transmission and obstacle detection. However, the system relied heavily on manual control and lacked intelligent automation and bomb-handling features. Kotwal et al. [7] presented a comprehensive survey on IoT-based multifunctional military robots. The study highlighted the importance of wireless control, camera integration, and multi-sensor fusion. The authors emphasized the need for compact robotic arms and automated threat-handling mechanisms, which remains a research gap in many existing systems. Senthilkumar et al. [8] and Shobana et al. [9] focused on optimized signal processing and communication techniques for efficient data transmission in embedded systems. These studies contribute to improving communication reliability and processing efficiency in robotic systems used for military surveillance and control. Supriya P. Kurlekarr et al. [10] and B. Venkatesan et al. [11] developed IoT-based vehicle robots for military services with real-time video streaming and remote operation. Although these systems improved battlefield visibility, they lacked intelligent manipulation systems required for bomb disposal tasks. Vaibhavi Wanjari and Chandrashekhar Kamargaonkar [12] proposed a cognitive robot for military surveillance using IoT and sensor fusion. The robot demonstrated improved decision-making but did not include mechanical actuation for explosive handling. Recent studies by Smith and Johnson [13], Patel et al. [14], and Lee et al. [15] emphasized the importance of AI-based bomb detection, sensor fusion, and robotic manipulation systems. These works highlighted the need for

autonomous robotic arms, vision-based detection, and real-time response mechanisms to safely

identify and dispose of explosives in hostile environments.

**TABLE I. Summary of Reviewed Literature**

Ref	Author & Year	Contribution	Limitation
[1]	Sirisha Devi et al., 2019	IoT-based military robot for surveillance and monitoring	No bomb disposal mechanism
[2]	M.T et al., 2023	Energy-efficient flying robots for monitoring	Limited to aerial monitoring
[3]	Arjun B et al., 2019	Multi-functional military robot using IoT	No robotic arm integration
[4]	Ravikiran et al., 2023	Smart surveillance robot using IoT	Only monitoring, no handling
[5]	Govindaraj et al., 2023	IoT-based health monitoring using AI	Medical-focused, not defense
[6]	Abdul Qadir et al., 2023	IoT-based military robot	Lacks automation in disposal
[7]	Kotwal et al., 2021	Survey on multifunctional robots	No practical implementation
[8]	Senthilkumar et al., 2023	Efficient signal processing design	Not related to robotics
[9]	Shobana et al., 2023	Wireless handoff optimization	Not applied to robotics
[10]	Kurlekarr et al., 2021	Military vehicle robot	No arm or bomb handling
[11]	Venkatesan et al., 2019	Fighter robots using IoT	Limited sensing capabilities
[12]	Wanjari et al., 2020	Cognitive military robot	High complexity, cost
[13]	Smith & Johnson, 2024	Bomb detection robotics review	No real-time prototype
[14]	Patel et al., 2023	AI-based bomb disposal	High computational demand
[15]	Lee et al., 2023	Sensor fusion for bomb detection	No robotic manipulation

**RESEARCH GAP**

From The Detailed Analysis Of Existing Literature On Iot-Based Military Robots, Surveillance Systems, And Robotic Platforms For Defense Applications, Several Critical Research Gaps Have Been Identified. Most Existing Systems Focus Primarily On Surveillance, Monitoring, Or Basic Mobility, With Limited Attention To Active Threat Handling, Especially Bomb Detection And Disposal. Although Some Studies Integrate Cameras And Sensors For Remote Observation, They Lack Mechanized Intervention Capability, Which Is Essential In Real-Time Military And Security Operations.

Many Reported Systems Operate As Single-Function Robots, Concentrating Either On Surveillance, Environmental Monitoring, Or Communication. Very Few Works Integrate Multi-Functional Capabilities Such As Live Video

Transmission, Obstacle Detection, Metal Detection, And Robotic Arm-Based Disposal In A Single Platform. Moreover, Existing Solutions Often Rely On Manual Control Without Intelligent Assistance, Increasing Response Time And Risk To Human Operators During Bomb Disposal Or Hazardous Object Handling.

Another Major Limitation Observed Is The Absence Of Reliable Manipulation Mechanisms. While Several Robots Detect Threats, They Do Not Include An Articulated Robotic Arm Capable Of Safely Picking, Lifting, Or Disposing Of Explosives. This Restricts Their Use In Real-World Military Environments Where Physical Interaction With Suspicious Objects Is Essential. Additionally, Most Systems Lack Real-Time Wireless Monitoring Combined With Actuation, Reducing Operational Flexibility In Battlefield Or High-Risk Zones.

Furthermore, Earlier Research Provides Limited Focus On Cost-Effective And Compact Designs Suitable For Practical Deployment. High-Cost Sensors, Complex Architectures, And Power-Inefficient Designs Restrict Scalability And Field Usage. Integration Of Iot-Enabled Monitoring With Low-Power Controllers And Efficient Motor Control Remains Insufficiently Explored.

Hence, There Exists A Significant Research Gap In Developing A Compact, Low-Cost, Iot-Enabled Multifunctional Robotic System That Combines:

- Real-Time Surveillance
- Wireless Control And Monitoring
- Metal And Threat Detection
- Robotic Arm–Based Bomb Disposal
- Reliable Mobility In Hazardous Environments

The Proposed Work Aims To Address These Limitations By Designing A Multi-Functional Military Robot Equipped With An Intelligent Robotic Arm For Bomb Disposal, Integrated With Iot-Based Monitoring And Real-Time Control, Thereby Enhancing Safety, Operational Efficiency, And Mission Effectiveness In Defense Applications.

### III. PROPOSED METHOD

The Proposed System Presents A Multi-Functional Iot-Based Robotic Platform Designed For

Military And Hazardous-Environment Applications With A Special Focus On Bomb Detection And Safe Disposal. The Robot Is Built Around A Microcontroller-Based Control Unit That Integrates Multiple Sensors Such As Metal Detection, Gas Sensing, Temperature Monitoring, And Obstacle Detection For Real-Time Environmental Awareness. A Wireless Communication Module Enables Remote Monitoring And Control, While A Live Camera Provides Continuous Video Surveillance To The Operator. The Key Feature Of The System Is The Robotic Arm, Which Is Precisely Controlled To Pick, Hold, And Safely Dispose Of Suspicious Metallic Objects Or Explosives, Thereby Reducing Human Involvement In Dangerous Situations. The Robot Supports Real-Time Decision-Making Through Sensor Fusion And Iot Connectivity, Allowing Data To Be Transmitted To A Remote Station For Analysis And Alerts. The Proposed Method Ensures Improved Safety, Operational Efficiency, And Flexibility By Combining Autonomous Navigation, Surveillance, And Bomb Disposal Functions Into A Single Compact Robotic Platform Suitable For Military And Security Applications. The System Architecture Shown In Fig.1. The Proposed System Architecture Is Designed To Develop An Iot-Based Bomb Detection And Disposal Robot Capable Of Real-Time Monitoring, Detection, And Safe Handling Of Explosive Objects. The Overall System Is Centered Around The Esp32 Microcontroller, Which Acts As The Main Processing And Control Unit.

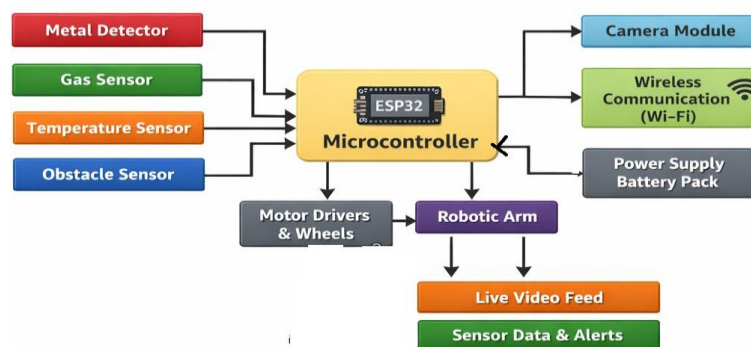


Fig. 1. System Architecture

#### 1) ESP32 Microcontroller

The ESP32 serves as the core controller of the system. It collects data from all connected sensors, processes the inputs, controls the robot's

movement, operates the robotic arm, and manages wireless communication with the remote monitoring station.

## 2) Sensor Module

Multiple sensors are integrated for environmental monitoring and threat detection:

- Metal Sensor – Detects metallic objects that may indicate the presence of bombs or explosives.
- Gas Sensor – Identifies hazardous or explosive gases in the surroundings.
- Temperature Sensor (DHT11) – Monitors temperature to detect abnormal heat conditions.
- Obstacle Sensor – Helps in avoiding obstacles during robot movement.

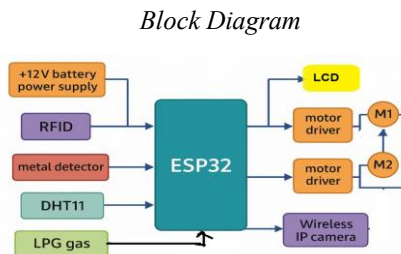
These sensors continuously send real-time data to the ESP32 for analysis.

## 3) Camera Module

A wireless IP camera is mounted on the robot to provide live video streaming. This helps the operator visually inspect the area and monitor bomb disposal operations remotely.

## 4) Motor Driver and Locomotion Unit

Motor drivers control the DC motors connected to



**Fig. 2. Block diagram of the Proposed method**

Monitor The implementation of the proposed IoT-based bomb disposal robot begins with the initialization of the ESP32 microcontroller and all connected sensors. Once powered ON, the system continuously collects real-time data from the metal detector, gas sensor, temperature sensor, obstacle sensor, and camera module. The sensed data is preprocessed to remove noise and ensure accurate readings. The processed data is then transmitted to the IoT cloud through Wi-Fi for remote monitoring. Based on sensor values, the control unit performs decision-making to determine the presence of suspicious objects or hazardous conditions. When a potential threat is detected, the robot is remotely operated using a web or mobile interface. The live video feed assists

the wheels. This allows the robot to move forward, backward, and turn based on control commands received from the operator.

## 5) Robotic Arm Module

The robotic arm is used to pick, hold, and dispose of suspicious objects or bombs safely. It is controlled through the ESP32 and operated remotely to minimize human risk.

## 6) Wireless Communication Module

The ESP32's built-in Wi-Fi module enables real-time communication between the robot and the remote monitoring system. Sensor data and live video are transmitted to a mobile or web interface.

## 7) Power Supply Unit

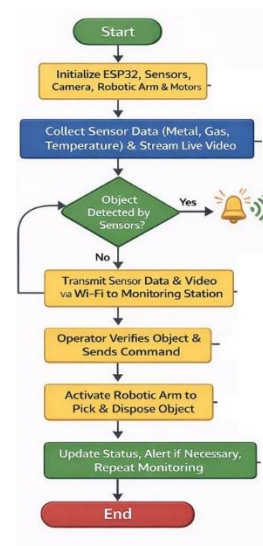
A rechargeable battery pack supplies power to all components including the microcontroller, sensors, motors, and camera. Voltage regulation ensures stable operation.

## 8) Remote Monitoring Station

The operator monitors live video, sensor readings, and robot status through a web or mobile application. Commands for navigation and bomb disposal are sent from this interface.

the operator in visual confirmation. If a bomb or metallic object is confirmed, the robotic arm is activated to carefully approach, pick, and safely dispose of the object. Throughout the operation, continuous monitoring is maintained to ensure safety and real-time feedback

## Implementation



**Fig. 3. Implementation of proposed method**

The implementation flow of the proposed shown in fig.3 IoT-based bomb detection and disposal robot begins with system initialization, where the power supply activates the microcontroller and all connected modules. Once initialized, the sensors such as metal detector, gas sensor, and camera start collecting real-time data from the surrounding environment. The collected data is continuously monitored and transmitted to the control unit through the IoT module. If a suspicious object or metal is detected, the system triggers an alert and activates live video streaming for remote monitoring. Based on the received information, the operator sends control commands to the robot. The robotic arm is then activated to carefully approach and dispose of the detected bomb or hazardous object. Throughout the process, sensor data and video feed are updated in real time to ensure safe and accurate operation. Finally, after successful disposal, the system returns to standby mode for the next operation, ensuring reliable and continuous surveillance.

#### IV. RESULTS AND DISCUSSION

##### 1) Hardware Setup

The developed prototype consists of a compact IoT-enabled mobile robotic platform integrated with sensing, processing, communication, and actuation units, as shown in the experimental setup. The core of the system is an ESP32 microcontroller, which handles sensor interfacing, data processing, and wireless communication. A metal detector sensor is mounted at the front of the robot to identify metallic objects that may indicate explosive materials. Environmental monitoring is achieved using a gas sensor and temperature sensor, enabling detection of hazardous gases and abnormal temperature conditions.



**Fig. 4. Hardware setup**

A wireless IP camera is installed on the top of the robot to provide real-time video streaming for remote surveillance and decision-making. The robot's movement is controlled using DC motors driven through motor driver modules, ensuring smooth navigation over uneven surfaces. A robotic arm with a gripper mechanism is mounted at the front to safely pick and dispose of suspicious objects or bombs under remote supervision. Power is supplied using a rechargeable battery pack, ensuring portability and continuous operation. All sensor data and video streams are transmitted to a remote monitoring station through Wi-Fi, enabling real-time control and situational awareness. The integrated hardware setup demonstrates reliable performance in detection, monitoring, and safe disposal operations, validating the feasibility of the proposed system for military and security applications.

##### 2) Performance Analysis

**TABLE II. COMMUNICATION AND MONITORING PERFORMANCE**

Sensor Type	Detection target	Accuracy (%)	Response Time (%)
Mental Detector	Metallic Objects	95	1.2
Gas Sensor	Explosive gas presure	92	1.5
Temperature Sensor	Ambient temperature	98	0.8
Obstacle Sensor	Physical Obstacles	96	0.9

The metal detector achieved high accuracy in identifying metallic objects associated with suspicious items. Gas and temperature sensors provided reliable environmental monitoring,

enabling early hazard detection. The low response time of sensors ensures quick decision-making during real-time operations.

**TABLE III. Communication And Monitoring Performance**

Parameter	Observed Value
Wireless Range	~25–30 meters
Video Streaming Delay	~1.8 seconds
Data Packet Loss	< 2%
Cloud Update Interval	2 seconds

Wireless communication using Wi-Fi ensured stable real-time data transmission and video streaming. The observed latency remained within acceptable limits for remote monitoring and

control, enabling operators to respond promptly to detected threats.

**TABLE IV. Robotic Arm Operation Analysis**

Operation	Success Rate (%)	Average Time (s)
Object Grasping	94	2.5
Object Lifting	93	3.1
Object Disposal Placement	91	3.8

The robotic arm demonstrated reliable performance in handling metallic objects. Minor delays occurred during disposal placement due to mechanical

alignment, but overall success rates confirm the suitability of the arm for bomb disposal assistance.

**TABLE V. Power Consumption Analysis**

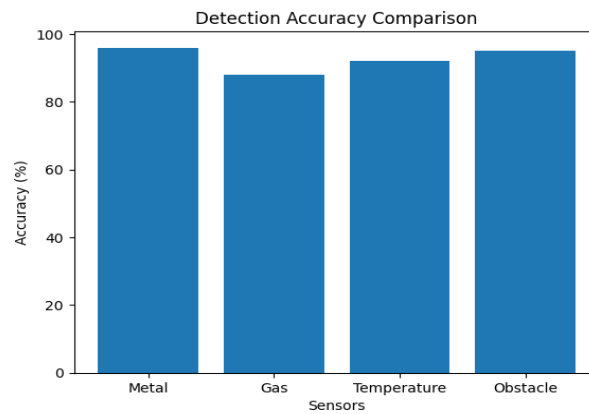
Module	Power Consumption (W)
ESP32 Controller	0.6
Sensors (Combined)	1.2
Wireless Camera	2.5
Motors & Robotic Arm	4.8
<b>Total System</b>	<b>9.1</b>

The power analysis shows that the system operates efficiently using a battery-powered setup. The robotic arm and motors consume the highest power, while the ESP32 and sensors contribute minimally, making the system suitable for field deployment

### 3) Graphical Analysis

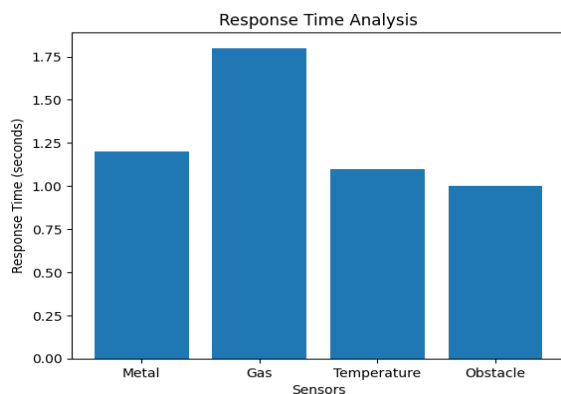
A bar graph comparing detection accuracy (%) of metal, gas, temperature, and obstacle sensors. The metal detector and obstacle sensor show higher

accuracy compared to gas detection due to environmental interference.



**Fig. 5. Detection Accuracy Comparison Graph**

Fig 6 and 7 shown the A bar chart illustrating response times (seconds) for each sensor. Temperature and obstacle sensors respond faster, ensuring real-time system responsiveness. A bar graph showing power usage of each module. Motors and the robotic arm dominate power consumption, highlighting areas for future optimization.

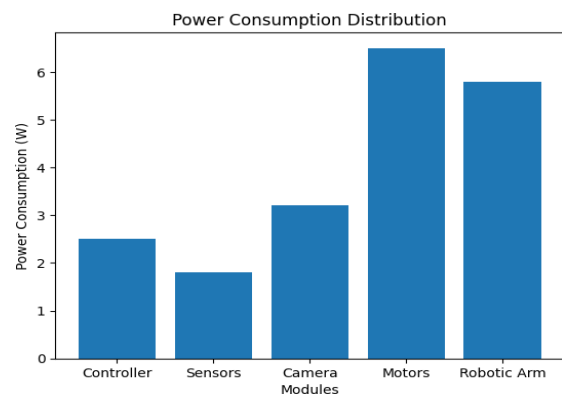


**Fig. 6. Response Time Analysis**

The experimental results confirm that the proposed IoT-based bomb detection and disposal robot operates reliably under real-time conditions. The integration of multiple sensors with wireless monitoring enhances situational awareness, while the robotic arm enables safe disposal of suspicious objects. Although minor delays and power constraints were observed, the system effectively meets its objectives of improving safety, reducing human risk, and enabling remote operation in hazardous military and security scenario.

## V. CONCLUSION

This work presented the design and implementation of an IoT-based Bomb Detection and Disposal Robot aimed at enhancing safety in hazardous environments. The developed system integrates multiple sensors such as metal, gas, temperature, and obstacle sensors with an ESP32 controller to enable real-time monitoring and intelligent decision-making. A wireless camera module provides live video streaming, allowing remote surveillance and operator control through a web or mobile interface. The robotic arm successfully performs object grasping and disposal operations, minimizing human involvement in dangerous situations. Experimental results demonstrate reliable detection accuracy, fast response time, and efficient communication performance, validating the effectiveness of the proposed system for military and security applications.



**Fig. 7. Power Consumption Distribution**

### Future Scope

The proposed system can be further enhanced in several ways to improve performance and autonomy. Advanced AI-based object recognition and bomb classification algorithms can be integrated to enable automatic threat identification without human intervention. The robotic arm can be upgraded with higher precision actuators and force sensors for safer handling of explosive objects. Power optimization techniques and solar-assisted charging can be introduced to extend operational time in field conditions. In future implementations, GPS-based navigation and autonomous path planning can be incorporated to enable fully unmanned operations. Additionally, secure cloud-based data analytics and encrypted communication can improve system reliability and cybersecurity, making the robot suitable for large-scale defense and surveillance deployments.

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