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# Defensive Innovations Against Kamikaze Drones: A Strategic Framework

Research About the Countermeasures for kamikaze drones' attack.

Nitin Semwal
*Computer Science Engineering Department*
*Chandigarh University*
Mohali, India
*22BCS10656@cuchd.in*

Er. Sanjay Singla
*Computer Science Engineering Department*
*Chandigarh University*
Mohali, India
*Sanjay.e13538@cumail.in*

Anshika Kumari
*Computer Science Engineering Department*
*Chandigarh University*
Mohali, India
*22BCS10074@cuchd.in*

Bhaskar Semwal
*Computer Science Engineering Department*
*Chandigarh University*
Mohali, India
*22BCS10717@cuchd.in*

Er. Narinder Yadav
*Computer Science Engineering Department*
*Chandigarh University*
Mohali, India
*Narinder.e16474@cuchd.in*

***Abstract* - *Who is Defending Against an Enemy That Uses Kamikaze Drones? — Now or in the future, kamikaze drones will cause a significant challenge for defense systems due to their speed, agility, and cost. Being mostly low and slow are exactly the characteristics that render these drones so difficult to defend against, for traditional defense mechanisms developed to engage higher, faster-moving targets have a hard time detecting and intercepting them in time. The low cost of kamikaze drones has made them a favoured weapon amongst adversaries, as virtuosos aspire to destabilize far-out sized military forces. That is the reliable source of the haunting requirement for original counter-measures that can furnish solutions. But for as commonly as these drones are being deployed, there is a serious dearth when it comes to technologies that can effectively thwart their attacks. To take on attacks like swarms of drones being launched at the same time, a next-generation air defense solution would need to counter high volumes of simultaneous and coordinated threats. This research examines the importance of increasing the chances of defeating targets with a direct contribution of sophisticated radar, directed energy devices, electronic warfare, as well as kinetic means. Some of the systems that we have come across and evaluated as a potential for destroying kamikaze drones include Epirus Leonidas (HPM) System, Giraffe 1X Radar, Oerlikon Skyshield, Phalanx CIWS, etc. Evaluating existing technologies and systems, this document seeks to offer a viable plan on how suicidal drone attacks can be countered thus bridging the current void in air defense mechanisms.***

**Keywords— UAV (Unmanned aerial vehicle), FPV (First-Person View), GNSS (Global Navigation Satellite Systems), HPM (High Power Microwave), DRDO (Defence Research and Development Organisation), CIWS (Close-in weapon System) and C-RAM (Counter rocket, artillery, and mortar).**

## I. INTRODUCTION

### *A. The History and Development of Drone Technology*

Although we frequently identify the name "drone" with the sophisticated aircraft of today, its origins date back much further, to a game called "Queen Bee". Drones have a long and diverse history that started with the first unmanned aerial vehicle (UAV), which was a basic hot air balloon that was launched in France in 1783. Since then, drone technology has advanced significantly, leading to the creation of suicide drones, or kamikaze drones. The name of these single-use, precision-strike drones is a reference to the Suicide drones tactics during World War II, Airmen carried out a missions intend to end their own life**.** The complicated and perhaps scary roles that drones have played throughout history are highlighted by this progression.[7]

### *B. Current Relevance and Challenges of Kamikaze Drones*

In today's fast-evolving technological landscape, kamikaze drones have become a pivotal force in modern warfare. These drones are no longer just experimental gadgets or theoretical ideas they are actively used on battlefields worldwide, demonstrating an unsettling precision in neutralizing high-value targets. The increasing availability of drone technology has enabled both state and non-state actors to acquire and deploy kamikaze drones, fundamentally altering the dynamics of asymmetric warfare.

However, the proliferation of these drones introduces significant challenges for military strategists and defense experts. One of the most critical issues is the difficulty in detecting and intercepting these small, nimble UAVs before they reach their targets. Traditional defense systems, which are typically designed to counter larger, slower threats, often struggle against the speed and unpredictability of kamikaze drones. Moreover, the relatively low cost of these drones,

compared to traditional weaponry, makes them an appealing option for those aiming to disrupt or weaken more powerful adversaries. This situation underscores the urgent need for innovative and effective countermeasures.

*C. Problem Statement with the importance of Problem*

Despite their increasing use, there remains a gap in understanding its countermeasures or how to stop them in crushing their attacks. The challenges they present to global security is although kamikaze drones are widely used by numerous countries. There is still a major deficiency in adequate techniques for deactivating or neutralizing these drones. As military and defence technologies are evolving and getting stronger day by day the capability to neutralize or counteract these drones has not inn equal speed as its development. Currently regular armies and militants are converting their drones into suicide drones by linking explosives to them. These drones, known as FPV (First-Person View) and many more but the idea for disabling or stopping it has not kept pace.

The growing deployment of kamikaze drones by various nations can create a severe problem in modern defense system .Although the evolution of kamikaze drones are in its peak but they are not focusing on an effective strategies for their deactivation or neutralization of the drones .As these strategies are growing and evolving extremist or insurgents can use them for jeopardize a nation or for some unappropriated task which is not good for our society .As these drones are cost effective , easy to make so many radicals , insurgents can use them for their irrelevant task. We need to develop advanced and effective methods for deploying and neutralizing these drones effectively to our nation and defence security.
This study basically aims to Countermeasures of kamikaze drones also known as suicidal drones, their evolution, solution to deploy it and making it stronger.

## II. LITERATURE REVIEW

*A. Introduction*

The expansion of Autonomous aerial vehicles widely known as suicide drones, kamikaze drones etc, has significantly altered modern warfare. Among the various applications of drones, kamikaze drones—designed for suicide missions to cause destruction upon impact—represent a growing threat. This literature review explores existing research and technological advancements in countering kamikaze drones, focusing on cost-effective methods.

*B. Evolutions and Components of Kamikazes drones*

Evolution in drones led to enhancement of their functionality and technologies. So here are some major technologies used in drones in missions and wars in modern days:

*a) Global Navigation Satellite Systems (GNSS):* GPS and GLONASS are the example of global navigation satellite system that is used by several drones for accurate navigation and placement of the drones to succeed the mission by Activating features like 3d mapping and search and rescue operation these drones has improved efficiency as it increases the chances of success. Global navigation satellite system has increase accuracy, Better Resource Allocation for navigating difficult terrain.

*b) Artificial Intelligence (AI):* AI helps to read large amount of data within very short period for quicker and faster approach and fast decision making. The idea behind merging Al with drones is to improve their operational functionality and to connect their range with solar cells so it can cover large distance.

*c) 3D Printing:* Different types of drones are built for different functions and they can have different body type and technology installed and required. The 3D printing technology is responsible for the body, propeller, and engine parts of drones can be modelled with the help of this technology. It even allows customization and faster testing.

*d) Battery Technologies:* Manufacturer uses lithium polymer or lithium-ion batteries in drones which is very important for power generation and performance. with configurations based on the number of cells to meet different voltage requirements [12].

*e) Communications Technologies:* Drones are often designed for wireless communication to set up connection for remote control and data transmission which is very important for their missions as Enhanced Operational Safety, Increased Range of Operations, Improved Coordination and many more including cost savings.*[1]*

Now the Components are Drones are often designed for wireless communication to set up connection for remote control and data transmission which is very important for their missions as Enhanced Operational Safety, Increased Range of Operations, Improved Coordination and many more including cost savings. The construction of drones is divided into two groups: -

***A. Movement system*** – It is responsible for the physical operations for the drones which allows the drone for navigation in the air. The Components in movement system contains: -

1. Propellers / Routers

Propellers emerge in different size, shape and material specifically designed based on its operation, commonly known as rotor or blade made of plastic usually. It requires regular changing and installation because it is the fragile and delicate parts of drone, can be easily damaged during flight, so preflight examine must be carried out in. [1]

2. Motors

Motor is the central figure of drones; it provides enough thrust to drones by making propellers spin which makes the drones ready for flight. The motion energy makes the propeller spin, as the electrical energy secured in the battery is converted to motion energy. Two variety of motors are used, the one with brush and another without

brush and it differ based on their dimensions, weight and freight for light drones, the motor with brush is favoured and for weighty and professional drones the motor without brush is used.[1]

3. Frame –

The frame is core and most important part of drones. It must design to be as lightweight as possible. It increases stability and improve flying efficiency. For the successful of missions, the propellers, motors, battery, camera, and receivers fit into the fuselage. F330, F450, and F550 models are the most preferred drone bodies. The drones can be Classified based on the number of arms (Fig 1.1),[4] and motors they use, as follows: [2]

1. **Dual-rotor copters** – two engines
2. **Triple-rotor copters** – three engines
3. **Quad-rotor copters** – four engines
4. **Hexa-rotor copters** – six engines
5. **Octa-rotor copters** – eight engines

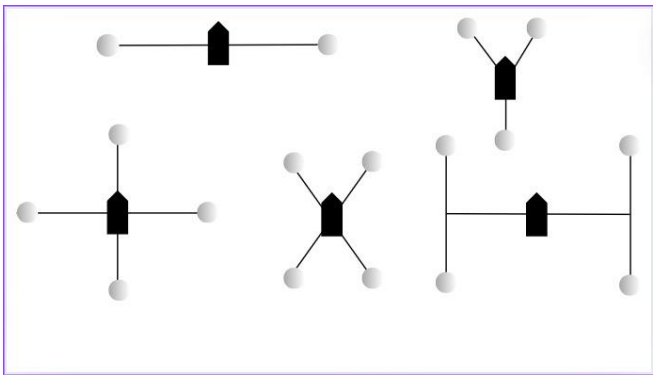

*Figure 1.1: Possible solutions of frame construction.*

4. Battery

Propellers can twirl more easily and efficiently because of the movement energy delivered by the lithium-ion or lithium polymer that is placed into the batteries and this is the reason of propeller to rotate easily. Numbers of the cells is responsible for the battery's specification in these defense drones and each cell aligns the voltage of 3.7 volts. [1]

5. Electric Speed Controllers (ESCs)

It is essential part of the drone to manage and regulate electrical motor speed, it necessitates a minor attention or servicing.[1]

***B. Control system*** – Its responsible for the movements of drones and according to the user's request and the commands. This includes: -

*1. Flight Controller*

Flight control cards usually known as brain of the drone. It deciphers signals from different cards, sensors, and receiver It is primarily a circuit board that turns on the UAV based on the sensor data it gets it sets the Pace and trajectory and turns on the camera by translating signals it receives into actions. *[1]*

*2.Camera*

Not every drone is equipped with a digital camera. Lens devices such as digital cameras or video cameras are extra added devices in drones as per its used.

The camera is installed ahead of the drones and image from the camera is transferred to pilot's monitor Alternatively glasses. The image is capture by sensor and transformed into a signal electrical. CCD AND CMOS are two sensors used in cameras. Assortment of data is done by CCD. CCD uses a scanning technique to Synchronously sort data, and it offers a superior dynamic range capacity. It performs admirably in low-light and blended light conditions.

When a data is grouped line by line from the pixels, it generates a jelly effect. CMOS sensor generally experience distortions with rolling shutter. The field view is directly depending on sensor size, the greater the sensor dimensions the wider the field view. As the lens size and low-light Performance enhanced. If the image is nearer, clear, and wider the smaller the field view.[1]

*3. Remote Controllers* - Drone controller and receiver are responsible for supervising and directing the drone. Receiver collects information from external source and convey them to flight controller. It activates the drone for movement as it detects the command from the remote control.[1]

*4. Autopilot System* – Not all drones are always controlled with the humans as kamikaze drones are now automated drones in which we set the location for the target and then drone launches and hit that targeted position.

## III. RESEARCH GAPS AND PROBLEM FOUNDATION

As in war the killing of UAV Swarm attacks took places in many steps which includes the operation concepts and operation process with decision making algorithms. [5]. The Overall algorithms for these operations are given in below diagram. The Research Gaps in our paper is divided into 4 parts with the problems foundations.

### *A. Identifications and Tracking*

Identifying huge amount of tiny, low flying kamikaze drones is extremely Arduous and challenging. Traditional radar system can have problem with low radar across this section of these drones. Their speedy and quick movements can overwhelm detection system.[11]

### *B. Engagement Complexities*

Handling the large number of drones attacks (i.e. Drone Swarm Attacks) needs the very sophisticated air defense system which

will completely counter the multiple drones simultaneously. Traditional Kinetic Systems are not sufficient because of the very high cost and the logistical constraints of intercepting each drone with missile.

### *C. Cost Efficiency*

The Cost of traditional kinetic defense like missiles against the drone swarm attack by kamikaze drones is prohibitively high because each drones need one missile which will increase the cost per drones.

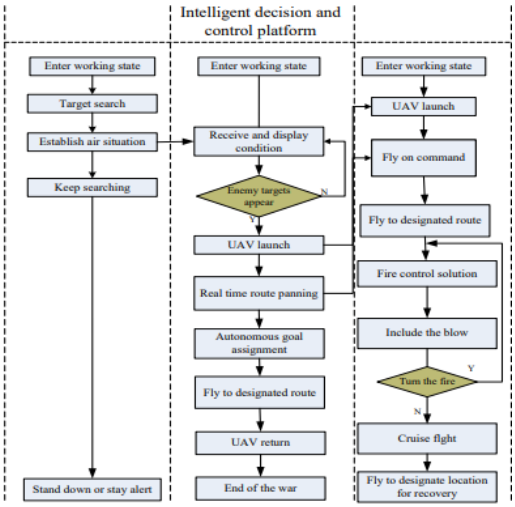


*Figure 2.1: The Flowchart for the air killing of drones*

### *D. Electronic Warfare and Countermeasures*

It is the warfare which uses the electromagnetic spectrum (i.e. Radio, Infrared, Radar etc.) for attacking and defending against the electronic systems of enemies. Modern Kamikaze drones are day by day becoming the more sophisticated with the electronic advancements. For Such countermeasures the defense system relies on the electronic warfare as a primary means of neutralizing drones.[6] It is important for gaining the control for disrupting enemy operations.

## IV. PROPOSED METHODOLOGY

To Effectively Counter the Problems, we have researched and proposed some multi-layered defense strategies for the counter measures of swarm attack done with the help of kamikaze drones. Our Proposed Solutions Includes various techniques which are related to the integrates advanced radar systems, directed energy weapons, electronic warfare, and the kinetic counter measures.

### *A. Giraffe 1X Radar*

This multi-mission radar is all-in one solution that helps the military for protecting themselves in any urgency and secure their freely movement up in the atmosphere. It Solve the main problem of Detection and Tracking with the main features of small structure and primitive look with lightweight and the effective 3d Radar [3]. It Also offers the constant upgradations in emergency threats.

### *B. Epirus Leonidas HPM System*

It is a small sized highly advanced defense technology which is designed to neutralized the drone swarm attacks which uses the high-powered microwave technologies for emitting the radiations to disrupts the drones from their positions and make them fall on the land with its high success probability as given in (Figure 3.1).[4] It solves the main problem of Engagements Complexities (By handling the high number of drones at a time) and the Cost Efficiency (with its key feature of one-many efficiency). This system is highly flexible and versatile in different combat scenarios.

### *C. DRDO Anti-Drone System:*

It is designed by India's Defence Research and Development Organisation (DRDO) for countering the growing threats UAVs including the kamikaze's drones. It is multi-layered defense integrated approach which neutralizes the drones by the jammers with range of about 3km. It is also equipped with the advanced radar systems with the exceptional low flying ability that might invade the conventional radar systems. It is solving the problem of detection and tracking (for detecting the drones and jam them in certain range) and Cost-effective nature for the economical countermeasure.

### *D. Oerlikon Skyshield:*

It is an advanced short range air defense system designed by Rheinmetall Air Defense to protect the important assets from various threats and it is also known for its precision and reliability. It has Advanced 35mm Revolver Cannons with the high rate of firing around the 1000 rounds per minutes, which also offers the full 360-degree coverage which will ensures it to be threats free.

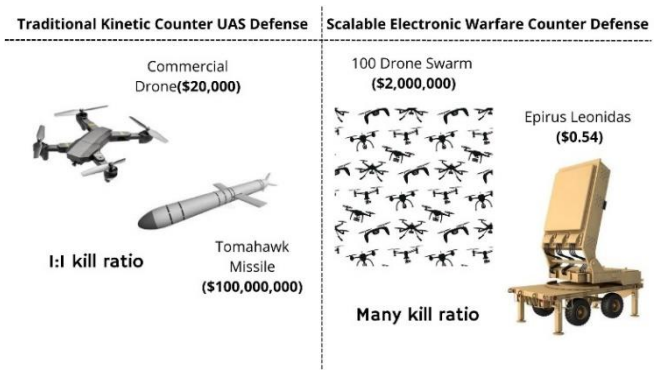


*Figure 3.1: Differentiate between the kinetic and electronic warfare counter defense.*

### *E. Phalanx CIWS (Land Version):*

It is a non-stop rapid-fire, radar-guided gun system designed primarily for naval defense against incoming missiles and aircraft. It has a land Version which is C-RAM used for countering the rockets, artillery, mortars, and drones. A 20mm Gatling gun is used here that can strike 4,500 rounds per minute providing a reliable hard-kill option. It is an Autonomous Target Acquisition and Multi-Target Tracking used for effective countering against the drone swarms. It also provides 360-degree coverage for countering in any direction. It can be

integrated with others defense system for the extreme layered defense strategy. It offers a more cost-effective solution for countering drones and attacking against rockets, artillery shells also shown in (Table 1.1) which can be used for protecting the airports, government buildings and military bases.

### *F. Iron Dome*

It is the mobile air defense system designed by Israel to demolish the SRR (Short Range Rockets), artillery shells and mortars strike to the critical assets of the countries. Its idea was developed after the 2006 Conflict of Israel and Hezbollah where they launched thousands rocket in their range which results the killing of Israeli citizens.[9] This System was developed by RADS (Rafael advanced Defense Systems) with the technological support of US. It became an official counter measure for the drones when firstly used in 2011. It is widely used in the Israel defense system for countering enemies' missiles and rockets.

It has 90% Success rate for hitting the targets which makes it highly effective for the defensive purpose. The key components for the functioning of the iron domes are mentioned below: -

1. *Detection and Tracking Radar (EL/M-2084):*
   It detects the incoming threats by tracking the trajectory and closely monitoring the flying objects in radar. It immediately sends the data to battle management and control unit (BMC) for the processing of data and tracking multiple targets simultaneously.
2. *Battle Management and Control (BMC) Unit:*
   It is also known as the brain of Iron Dome system, used for the decision making by processing the information provided by the radar.
3. Missile Firing Unit (MFU):
   It houses the TAMIR interceptor missiles which are used to destroy the enemies' missiles and drones. It is highly maneuverable and known for its precise attacks.

## V. RESULTS AND DISCUSSION

This portion of the research paper represents the results of simulations and testing which are conducted to analysis the effectiveness of various countermeasures against the swarm attacks by kamikaze drones in different scenarios in terms of the Attack Pattern, Environment Condition for the warfare as given in below table (Table 1.1) [4]

| Scenarios | Swarm Size | Attack Pattern | Environmental conditions | Counter Measure Tested |
|---|---|---|---|---|
| **A** | 20 drones | Linear approach | Clear weather, open terrain | Phalanx CIWS, Giraffe 1X Radar |
| **B** | 50 drones | Coordinated muti-directional approach | Foggy weather, urban environment | Epirus Leonidas HPM System, DRDO Anti-Drone System |
| **C** | 100 drones | Randomized zig-zag approach | Mixed weather, forested terrain | Phalanx CIWS, Iron Dome |
| **D** | 200 drones | Complex multi-layered approach | Stormy weather, mountainous terrain | Counter UAS Jammer, Phalanx CIWS |

*Table 1.1: Showing the efficiency of each counter technique with respect to the different war conditions.*

The above analyzation for this study resulted that from the above systems evaluated, the Epirus Leonidas HPM system, Counter UAS Jammer, Iron Dome emerged as a most efficient solution to neutralize the multiple drones simultaneously using the high-power microwave technology, electric and kinetic technologies.

The Oerlikon Skyshield and Phalanx CIWS systems uses the kinetic technology that plays a crucial role of securing the countries from different causalities. This Skyshield has the high rate of fire and precise target killing of the multiple drones simultaneously in the air.

The comparative study presented that the importance of highly secured multiple defense technologies to counter the modern combat scenarios. While each discussed system has its strength, effectiveness according to their environmental conditions. The integrated approach of all resources above mentioned will be highly beneficial for the country itself because of their effectiveness, precision, robustness.

## VI. CONCLUSIONS

This research paper is focused on the daily threats of kamikaze drones' swarms attack in modern attack and the evaluation of very advanced and multilayered defense systems to counters the multiple drones simultaneously without casualties. We have focused on the problems facing in old defense systems when used against the swarms' attacks. This research has identified and analyzed some of the systems like the Epirus Leonidas HPM system, Giraffe 1X Radar, Oerlikon Skyshield, Phalanx CIWS and Iron domes which offers the effective ways to neutralizes such kind of attacks.

Giraffe 1X Radar is the automatic tracking radar with its fast detection of 600 air targets simultaneously in air which makes it more responsive for the multilayered defense strategies. Oerlikon Skyshield has the high rate of fire and known for its precision for shooting targets which makes it particularly effective for neutralizing the drones. Phalanx CIWS and Iron

domes are the modern advanced defense strategies that can be used for killing the multiple drones in air simultaneously with precision attacks.[10]

The research also focused for the importance of integrating the multiple systems together to a complete comprehensive defense network for neutralizing attacks in war combats Through comparative analysis, it was demonstrated that not only a single system will be completely enough to handle such bigger swarm attacks together but they can be sufficient when the electronic and kinetic defense mechanisms will be integrated together. Above proposed solutions are the cost effectiveness and specially the Epirus Leonidas HPM System is noted for cost-effectiveness which offers the low many to one kill ratio.

The advancements discussed are broad implications for the national securities and must be collaborated across the nations for the technological advancements. The conclusion shows the need for collaborations at different levels between different defense agencies, governments for developing the advanced secured and defensive systems.

## VII. FUTURE SCOPE

The deployment of countermeasures against kamikaze drones or any loitering munitions, is a rapidly evolving field. Continuous innovation in effective defense strategies is required to make precise counter measures for these drones which are very sophisticated in nature. The future scope for countermeasures involves several ways:

ADS (Advanced Defense System): Future research will focus on improving detection technologies, including radar systems, infrared sensors, and acoustic detectors, just to identify the kamikaze drones at their earlier stages of flight. It also includes some more advance features such as Detecting small, Low flying and stealthy drones with minimal false positives. It will include AI-powered detection with real time analytics which could greatly enhance the precision and response time of the defense systems.

DEW (Directed Energy Weapons): Advancement in this domain in future will be high energy lasers and microwave weapons, in near future there will be more precise as well as more cost-effective means should be there as to neutralize kamikaze drones. In this additional feature will get added like providing repeatable defense capabilities.[8]

International Collaboration and Standardization: Drone is now a global threat in current time as well as in near future, researches will emphasize international collaboration to develop standardized counter-drone technologies. This will facilitate the sharing of data, strategies, and technological advancement among nations, improving global defenses against kamikaze drones.

Cybersecurity and Drone Hacking: Another method is by exploring cyber warfare techniques to take control of hostile kamikaze drones for future countermeasures. As we know Cyberattacks are the ones having the potential to hijack the Drone's main command system which directly allows defense forces to either neutralize the drone against its original operators.[6]

Swarm Countermeasures: As we can see the rapid growth of swarm tactics by Kamikaze drones, therefore future countermeasures will be focusing on their swarm defense strategies. This also includes the defensive drone swarm which is particularly designed to neutralize offensive swarms through kinetic or electronic means. In near future the research into Collaborative defense networks as well as the decentralized defense networks, both can communicate and respond to threats collectively will be key.

These areas of research and technological advancement will be crucial in developing comprehensive defense mechanisms to counter the growing threat of kamikaze drones, ensuring national security and the protection of critical infrastructure.

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