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# Counter-UAV Systems

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***Abstract***

*An unmanned aerial vehicle is an aircraft that moves autonomously or can be controlled remotely and equipped with a useful load. It is now used in many fields such as agriculture, military and civilian. UAVs are preferred because they are affordable and have a more advantageous scope of use than aircraft. Countries have used it in various battles because of these advantages, and even UAVs have changed the course of battles. Together with these advantages, UAVs have been preferred to terrorist groups for attack purposes and have become a threat to countries. The threat has led countries to seek defence systems against UAVs. In this context, the study discusses the use of UAVs in warfare after general information has been provided. Subsequently, examples of UAV attacks by terrorist groups were cited. Methods for detecting UAVs have been continued and methods for disabling them have also been studied. In the light of all this information, it is estimated that the use of UAVs as a threat will increase, and in this context the development of defence systems against the UAV will be critical.*

***Index Terms:*** *UAV, anti-uav system, counter uav system, detecting, neutralizing, uav attacks, unmanned aerial vehicle.*

## 1. Introduction

With the rapid development of technology, unmanned Aerial vehicles (UAVs) have emerged. UAVs do not have a single definition. Countries and institutions have given various definitions to UAV. According to the definition made by ICAO, which was established in 1947 and has the task of ensuring the safe and orderly growth of international civil aviation, An unmanned aerial vehicle is a pilotless aircraft, in the sense of Article 8 of the Convention on International Civil Aviation, that is flown without a pilot-in-command on board and is either remotely and fully controlled from another place (ground, another aircraft, space) or programmed and fully autonomous. [1] The variety of custom-built UAVs has also increased and has been categorized to identify them. UAVs are categorized into items such as usage area of the aircraft, wing type, and flight altitude. [2]

Besides being cheaper and smaller, UAVs occupy a large place in human life because of their advantages, such as being able to be used in hazardous areas, having a low radar range, and requiring less human power. These instruments are supported in many areas, such as agriculture, the military, and civilian life. [3]. The most prominent area in the field of use is the military, which also affects the security of countries. In the military field, UAVs are preferred for various purposes, such as exploration, surveillance, protection, and attack. UAVs that left their mark on history, such as the Bayraktar TB2, Aknc, ANKA, MQ-9 Reaper, MQ-4, and Herons, were produced. Bayraktar TB-2, produced by Baykar in Turkey, changes the course of the Nagorno-Karabakh war and Ukraine. TB-2 and ANKA play an active role in the fight against terrorism and border protection. The MQ-9 Repear, produced by the US company General Atomics Aeronautical Systems, has been used in the fight against DAESH in Iraq, Syria, and Afghanistan and is currently used in active operations and in tasks such as border patrols. In addition to the above-mentioned UAVs, there are a large number of UAVs produced by different states. UAVs are increasingly used for both useful and harmful purposes. While terrorist groups are closely monitoring technological developments, their attacks are inevitably supported by UAVs. Because UAVs are easily accessible and cheap, terrorist groups, in particular, have begun to use them to attack countries. In this context, the first example of the use of unmanned aerial vehicles for offensive purposes was seen in the attacks carried out by the Austrians with balloons loaded with time bombs on the city of Venice on August 22, 1849. [4] Terrorists have also attempted various UAV attacks against Turkey. For example, a bombed drone in 2016 [5], a Turkish base in Northern Iraq in 2021 [6], and the 8th Main Jet Base Command in 2021 [7] were attempted by PKK terrorists. But Turkey's military efforts to combat terrorism, in particular, have pushed the terrorists into

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the corner. When the examples around the world are examined, it is seen that UAV attacks were carried out against Russia's Hmeymim and Tartus bases in Syria in 2018 [8], the oil producer Aramco Company, which is important for the world's countries, in Saudi Arabia in 2019 [9] and 2022 [10], and the Abu Dhabi airport in Abu Dhabi, the capital of the United Arab Emirates, in 2022 [11].

UAV attacks cause major damage to critical sites such as security, energy lines, and military bases. As a result, countries have begun to produce anti-UAV systems in search of solutions.

In this study, detection methods and neutralization methods for UAVs that pose a threat are examined.

## 2. Counter-UAV Systems?

In general, an Anti-UAV System Architecture can be examined under two subheadings.[12]

1- Detection-Diagnosis-Tracking System
2- Prevention System

Counter-UAV System architecture created by Meteksan is presented in the figure below. [13]


When the above table is examined, first of all, UAV' is detected through various Sensor Systems such as Radar, EO/IR, RF-DF, and Acoustic. Then, after clasifying with Command and Control System, the UAV, which is a threat with Soft-Kill or Hard-Kill Systems, is neutralized.

### 2.1 Detection-Diagnosis-Tracking System

#### 2.1.1 RADAR

When the basic working principle of RADAR is examined, it is seen that it is similar to that of sound wave reflection. It uses electromagnetic energy pulses for the detection and location of the objects. [14] If electromagnetic waves sent from the transmit section of the radar encounter an obstacle, they are reflected back from this obstacle. These reflected back waves are received by the receiver part of the radar. Thanks to the algorithms of the RADAR, features such as position, speed, and altitude are determined according to the features of the radar. There are many types of radars that can be used according to need. However, there are various limitations to the detection capabilities of existing radars. The most important of these is the geographical constraint. If the land where the radar is deployed has a rough structure, detection weakness occurs at the back of this rough section. At the same time, military radars have limitations in low-altitude detection. In this context, there may be problems with the detection of UAVs that can fly at low altitudes. [14] However, it is considered that this problem can be overcome by including low-altitude radars in the system.

With Secondary RADARs, aircraft with transponder devices can be detected. The aircraft, which has a transponder device, responds to the query made by the Secondary Radars working with query and answer logic. The response sent by the aircraft includes information such as position, altitude, and status. [14] However, UAVs used for attack cannot be detected by secondary radar, either because they do not have this device or because the device is turned off.

#### 2.1.2 E/O and I/R Method

One of the methods of detecting UAVs is using Electro-Optic (EO) systems. In these systems, when it is desired to increase the range to be observed, the scanning angle of the camera decreases. If the range to be observed decreases at the same rate, the angle of the camera increases. For this reason, UAVs must be in sight in order to be detected by this system. [15]

The Infrared(IR)/Thermal Camera method is made using infrared energy emitted from objects and cannot be detected by the human eye. This method, in which the temperatures of the target appear in different color tones, is not affected by bad air temperatures. [16] However, the biggest limitation of this method is that it must be in the field of view to detect the UAV.

#### 2.1.3 RF Method

Unmanned aerial vehicles are generally guided via a ground control station. The ground control station communicates with the UAV via RF (Radio Frequency) signals. In this method, the UAV is detected by monitoring RF signals. [18] The disadvantage of the RF method is the availability of autonomous and pre-programmable UAVs. The mentioned UAVs cannot be detected as they do not emit any RF waves and do not communicate with the ground control station in any way. In addition to this limitation, it can prevent the system from working properly by generating faulty RF signals, especially in places where there are many electromagnetic broadcast sources (communication antennas, radios, telemetry systems, and power transmission lines). [12]

#### 2.1.4 Acoustic Method

In this method, the UAV is classified by comparing the previously created library by collecting-defining-detection of the audio signal coming from the rotor or engine of the UAV. In addition, the related system allows learning of locations. [17] However, the most important limitation of this system is that it is adversely affected by weather conditions and environmental noise.[18]

#### 2.1.5 Multisensor Method

It has been examined in the previous chapters that UAVs can be affected by the environment and have many inadequacies if detection-diagnosis-follow-up methods are used alone. It has been stated that when the Acoustic Method is used, it is affected by environmental conditions, and when the RF method is used, different RF waves in the environment have negative effects when detecting UAVs. In this context, it is considered that using these methods in multiples instead of using them alone may be more effective in combating UAV. For example, a UAV that comes at a very low altitude and may be a threat may not be detected by radar. However, the

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presence of the UAV can be detected by detecting the RF sensors of the communication network between the UAV and the ground station. Likewise, a UAV that uses its block at mid-altitude and performs autonomous flight cannot be detected with RF sensors but can be detected with radar. With the examples mentioned, it is stated how effective the use of multisensors can be in the fight against UAV. In the next part of the study, methods of neutralizing UAVs will be explained.

### 2.2 Neutralizing Methods

#### 2.2.1 GPS Jamming

Another method of neutralizing UAVs is GPS (Global Positioning System) Jamming. First, if the definition of GPS is examined, it is understood that it is a satellite-based radio navigation system operated by the United States Space Force. [19] In general, a GPS receiver located anywhere in the world provides location and time information thanks to 4 or more nobstructed line of sight satellites used in the system. GPS is also very common in UAVs. With the GPS system in the UAVs, the location of the UAVs can be known as coordinates by the users. However, it is possible for this GPS system to be jammed as well. When UAVs using the GPS system are jammed, the UAV loses its positioning capability. In this way, the ground station user sees the location of the UAV as it has gone to the desired location in the system. But the UAV would be shifted to a different spot. As can be seen many examples in the world where this system is used, an example from Turkey is İLTER Drone/UAV Detection and Neutralization System produced by Boğaziçi Defense Company. This system detects the communication band between the UAV and the ground station. If it detects an autonomous UAV flight afterwards, it enables it to go to a different point by GPS Jamming. [21]

#### 2.2.2 RF Jamming

Another UAV neutralization method is RF Jamming. This method is generally based on the principle of preventing a wireless device from communicating with other devices/networks. [22] If a UAV's wireless communication with the ground station is interrupted, four situations may be encountered.[20]

a) Controlled landing of the UAV,
b) UAV goes to predetermined home,
c) Uncontrolled fall of the UAV,
d) It is the UAV flying in a random uncontrolled direction.

However, since this method is a jammer against RF signals, it may affect other systems such as mobile phone lines in the vicinity.

In this method, it is a highly preferred method in the world. If we give an example of its usage in Turkey, it is the İHTAR system produced by Aselsan. The system detects UAVs thanks to its ACAR radar. The communication of the detected UAV can be interrupted by the GERGEDAN RF Jamming System. [23]

#### 2.2.3 Net

One of the ways to disable UAVs is to use the net. It is used for smaller-diameter UAVs as opposed to larger UAVs. The network method used to neutralize UAVs can be examined under two general headings. In the first method, the threatened UAV can be captured or shot down by a UAV carrying a net. The UAV, which was found to be carrying radioactive material on the roof of the Japanese prime minister's building in 2015, was neutralized by a UAV carrying a net.[24]

The second method is to neutralize the threat UAV by networking with the help of a device/weapon. Skywall 100, produced by the UK company, enables the UAV to be neutralized by throwing a net with a gun.[24]

The additionally produced SkyNet Mi-5 shells, on the other hand, become a network by going to the threat UAV after being fired. Then the threat UAV is neutralized.[25]

#### 2.2.4 Spoofing

Another method of neutralizing threatening UAVs is spoofing. Spoofing works with the logic of imitating the signals received by remotely controlled or GPS-guided autonomous UAVs, taking control or misdirecting them.[12] According to the published news, it was claimed that a student hacked the drone within minutes at the Cyber Security Weekend organized by Kaspersky Lab in 2019.[26] This news revealed that UAVs can be easily hacked.

#### 2.2.5 Birds

Birds used by humans for their hunting needs have begun to be used to neutralize UAVs. Birds of prey, which are usually selected from eagles and given special training, started to be used in the fight against small UAVs. After the observation of UAVs in critical areas in Paris in 2015, it was stated that the French Air Force trained 4 eagles to neutralize the UAVs. [27]

#### 2.2.6 Laser

Another method of neutralizing UAVs is the use of lasers. This method, on the other hand, is to direct the laser light to the UAV, burn it, and neutralize it. In addition, the efficiency of the laser is directly proportional to the material the UAV is made of. When the UAV is made of durable material that does not ignite easily, the time required to be kept on the beam for it to burn becomes longer.[12] An important disadvantage of the laser method is its high cost. It is evaluated that the high cost reduces the spread rate of these systems. For example, there is the High-Energy Laser Weapon System under development by Raytheon Technology, which is planned to be used against threats such as howitzers and UAVs. The tests of this system are still ongoing.[28]

#### 2.2.7 Weapons

Another method examined in the study is to neutralize the UAV with a shot made by a personnel. The most important disadvantage of this method, which can be used mostly for UAVs flying at low altitudes, is the miss. If care is not taken while using this system, loss of life may result.

#### 2.2.8 Multi-Intervention System

The last method to be examined in the study is the Multi-Intervention System. This method, on the other hand, is to increase the rate of inactivation of the UAV and prevent

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damage by using the methods described together. However, it is considered that the disadvantage of this method will be its cost due to the use of multiple systems.

## 3. CONCLUSION

With the development of technology, UAVs have emerged and their use has increased due to their advantages. It has been explained that the UAVs are used for purposes as well as their useful use. In this context, examples of UAV attacks against countries are given. Due to the great threat of UAVs to countries, it has led to the search for a defense system. In this context, it has been examined that the systems produced consist of detection, diagnosis, and prevention sub-sections. The most important step of the system is detection. Because if UAVs cannot be detected, they cannot be neutralized. For this reason, it has been announced that the first stage of neutralizing is the detection of UAVs. Neutralizing methods used to neutralize the detected UAVs were examined. In the light of all this information, it is evaluated that the use of UAVs as a threat will increase, the use of the methods used alone may be insufficient, and therefore it will be critical to develop defense systems against UAVs.

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