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Conceptualising Counter-Drone Systems: A New Arms Race in South Asia

Abdullah Rehman Butt

Abstract

In contemporary times, drones have evolved into an essential tool of modern warfare and a rapidly growing element of airpower. Drones of varying sizes, speed, types, and capabilities are being used by modern militaries for a variety of roles. The manifestation of novel concepts like 'Loyal Wingman' and 'Swarming' has further added to their lethality. Hence, defending against such credible threats has become a complex as well as daunting task for the militaries of this era. This raises the need for appropriate air defence systems to detect and, if required, bring down unauthorised drones. Their massive proliferation in both civil and security domains, as well as existing gaps in aerial defence systems, are the fundamental drivers of the tremendous development of the market for counter-drone systems. This paper aims at conceptualising modern counter-drone systems, as well as their threat mitigation process and capabilities. It also intends to provide insight about how Indian acquisitions in this domain are triggering an arms race in South Asia which would have serious consequences for regional stability.

Keywords: C-UAS, Counter-Drone Systems, Arms Race, Strategic Stability, India-Pakistan.

Introduction

In contemporary times, drones—also called Unmanned Aerial Vehicles (UAVs), Unmanned Aerial Systems (UAS), or Remotely Piloted Vehicles (RPVs) — have evolved into an essential tool of modern warfare and a rapidly growing element of airpower. The idea of UAVs was first adopted by the Austrian military when they employed unmanned balloons packed with explosives to strike enemy positions in Venice in 1849.[1] Since then, they have been used for different roles in various military campaigns around the world including both World Wars, Vietnam War, Gulf War, Iraq War, Operation Enduring Freedom, Nagorno-Karabakh War, and more recently in the Russia-Ukraine War.[2] During the late Twentieth Century, development of UAVs witnessed unprecedented growth as improvement in technology matched with the idea of uninhabited aircraft and rendered massive horizontal and vertical proliferation of these systems.

For instance, between 2002 and 2010, the United States (US) military's fleet of UAVs grew forty-fold,[3] driven by the wars in Afghanistan and Iraq, where they were used for surveillance, reconnaissance, and later, for targeted strikes. Since the 1990s, UAVs have become an integral part of US military operations, with various types being employed, such as the MQ-1C Gray Eagle, MQ-9 Reaper, MQ-25 Stingray, RQ-4 Global Hawk, MQ-4C Triton, and RQ-170 Sentinel. These developments indicate a steady increase in the use and complexity of UAVs in military operations. While exact numbers have varied over the years, there has been a clear

1 Kashyap Vyas, "A Brief History of Drones: The Remote Controlled Unmanned Aerial Vehicles (UAVs)," *Interesting Engineering*, June 29, 2020, https://interestingengineering.com/a-brief-history-of-drones-the-remote-controlled-unmanned-aerial-vehicles-uavs.

2 Jonathan Marcus, "Combat Drones: We Are in a New Era of Warfare - Here's Why," *BBC News*, February 4, 2022, sec. World, https://www.bbc.com/news/world-60047328.

3 John Hill and Ann Rogers, *Unmanned: Drone Warfare and Global Security* (London: Pluto Press, 2014).

trend of increasing quantities. For instance, the MQ-1 Predator, which was one of the first widely used UAVs by the US military, saw its numbers grow significantly in the first decade of the 2000s before being phased out for more advanced models. The number of other countries possessing UAVs (with diverse capabilities) has hiked up to more than 95.[4] The Indian Armed Forces have operated over 200 Medium Altitude Long Endurance (MALE) Searcher and Heron UAVs of Israeli origin, along with a few HAROP UAVs recently inducted by the Indian Air Force (IAF). These UAVs have been essential for surveillance along India's borders and coastal areas, and they have seen service in various regions, including Indian Occupied Jammu and Kashmir and the Sino-Indian border. The Indian Armed Forces plan to induct 5,000 UAVs in the next ten years, marking a substantial increase and demonstrating the growing role of UAVs in modern military strategy. This expansion reflects the increasing importance of UAVs as force multipliers.

Now, UAVs of varying sizes, speed, types, and capabilities are being used by modern militaries for a variety of roles including ISR (for real-time data collection, target identification, greater battlefield awareness), attack (air-to-air and air-to-ground precision strikes, SEAD and DEAD missions[5]), and combat support

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4 Dan Gettinger, *The Drone DataBook* (New York: Center for the Study of the Drones, Bard College, 2019), https://dronecenter.bard.edu/files/2019/10/CSD-Drone-Databook-Web.pdf.

5 SEAD (Suppression of Enemy Air Defences) missions involve the use of specialised aircraft and weapons to suppress or destroy enemy air defence systems such as radar and surface-to-air missile sites. These missions are typically conducted at the beginning of a larger air campaign to ensure that friendly aircraft can operate safely and effectively in the airspace. DEAD (Destruction of Enemy Air Defences) missions are similar to SEAD missions but involve a more aggressive approach, often involving larger-scale attacks on enemy air defence systems with the goal of completely destroying them. These missions

(electronic warfare, early warning, communication relay, search and rescue missions, logistics, training).[6] Relentless advances in this domain and related technologies, low production and in-service costs, easy and effective deployability, precision in both navigation and attack capabilities, and integration with Artificial Intelligence (AI) have transformed them into a significant conventional war-fighting asset for states. For example, in their defence budget for fiscal 2025, the US government is planning to allocate USD 1 billion to create a hedge portfolio for drones with AI capabilities under a newly introduced 'Replicator' programme. For fiscal 2024, the US Department of Defense (DoD) has sought USD 1.8 billion specifically for AI projects. As of 2021, it was supervising over 685 AI-related initiatives.[7]

The manifestation of novel concepts like 'Loyal Wingman'[8] and 'Swarming'[9] has further added to their lethality and given a boost to investments in this technology around the globe. 'Loyal Wingman' drones are being developed by the US to fly alongside expensive new jets like the F-35 with plans for 1,000 of these

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may be conducted as part of a larger offensive campaign, or in response to a specific threat or incident.

6 National Research Council, *Autonomous Vehicles in Support of Naval Operations* (Washington, D.C: The National Academies Press, 2005), https://doi.org/10.17226/11379.

7 Noah Robertson, "Pentagon Unveils 'Replicator' Drone Program to Compete with China," *Defense News*, August 28, 2023, https://www.defensenews.com/pentagon/2023/08/28/pentagon-unveils-replicator-drone-program-to-compete-with-china/.

8 Garrett Reim, "US Air Force 'Commits' to Fielding Loyal Wingman UAVs," *Flight Global*, December 11, 2021, https://www.flightglobal.com/military-uavs/us-air-force-commits-to-fielding-loyal-wingman-uavs/146802.article.

9 David Hambling, "What Are Drone Swarms and Why Does Every Military Suddenly Want One?," *Forbes*, March 1, 2021, https://www.forbes.com/sites/davidhambling/2021/03/01/what-are-drone-swarms-and-why-does-everyone-suddenly-want-one/.

'collaborative combat aircraft' in 2024.[10] 'Loitering munitions' — drones that can circle the battlefield and divebomb targets on their own — are being developed by numerous countries, and have already seen combat in Libya, Armenia and Ukraine.[11] Hence, defending against such credible threats has become a complex as well as daunting task for militaries of this era. Resultantly, technologies to counter them will become a vital and omnipresent weapon for states in future conflicts.[12]

Apart from rapid adoption in the military domain, the commercial sector has also witnessed an exponential growth of small UAVs and their applications during the last few years. Resultantly, they are getting more sophisticated, cheaper, and easily available for everyone in the civil sector. While this unlocks more options for beneficial usage, it also gives space to malevolent actors to employ these capabilities for illicit activities. Likewise, non-state actors, as well as terrorist groups, are increasingly using commercially available small drones as a weapon of choice for their desired purposes, with varying degrees of success.

The ever-increasing traffic of civil drones is also posing some serious challenges for Air-Traffic Management Systems around

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10 Stephen Losey, "US Air Force eyes Fleet of 1,000 Drone Wingmen as Planning Accelerates," *Defense News*, March 8, 2023, https://www.defensenews.com/air/2023/03/08/us-air-force-eyes-fleet-of-1000-drone-wingmen-as-planning-accelerates/.

11 Eva Dou and Gerrit De Vynck, "Pentagon Plans a Drone Army to Counter China's Market Dominance," *Washington Post*, December 1, 223, https://www.washingtonpost.com/technology/2023/12/01/pentagon-drones-replicator-ukraine/.

12 Arthur Holland Michel, *Counter Drone Systems*, report (New York: Center for the Study of the Drone, Bard College, December 2019), https://dronecenter.bard.edu/files/2019/12/CSD-CUAS-2nd-Edition-Web.pdf.

the world.[13] As a result, the proliferation of small Commercial Off-The-Shelf (COTS) UAVs poses a substantial threat to both the safety and security of civilians as well as military installations.[14] For instance, in 2019, a drone sighted near Gatwick Airport in the United Kingdom (UK) affected the schedule of 1000 national and international flights.[15] A similar incident happened in Germany in May 2019 and March 2020, when several flights were cancelled and diverted after small drones appeared near Frankfurt Airport.[16] In 2019, a drone strike on a Saudi oilfield disrupted the production of 5.7 million barrels of crude oil, causing major disruptions in global fuel supplies.[17]

All these asymmetric threats and aforementioned factors raise the need for appropriate Air Defence Systems (ADS) to detect and, if required, bring down unauthorised drones. Conventional air defence systems employed to defend against traditional aerial threats have limitations against small, slow-moving, low-flying UAVs.[18] For instance, a simple drone entered Israel from Syria and

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13 Zsolt Sándor, "Challenges caused by the Unmanned Aerial Vehicle in Air Traffic Management," *Periodica Polytechnica Transportation Engineering* 47, no. 2 (2019): 96–105, https://doi.org/10.3311/PPtr.11204.

14 Thomas G. Pledger, *The Role of Drones in Future Terrorist Attacks*, report (Association of the United States Army, February 2021), https://www.ausa.org/sites/default/files/publications/LWP-137-The-Role-of-Drones-in-Future-Terrorist-Attacks_0.pdf.

15 Justin Rowlatt, "Gatwick Drone Attack Possible Inside Job, Say Police," *BBC News*, April 14, 2019, sec. UK, https://www.bbc.com/news/uk-47919680.

16 "Frankfurt Flights Suspended Twice for Drone Sightings," *Reuters*, March 2, 2020, sec. Industrials, https://www.reuters.com/article/us-germany-airport-drone-idUSKBN20P1O8.

17 Associated Press, "Drone Attack on World's Largest Oil Processing Site Sparks Huge Fire," *NBC News*, accessed March 26, 2022, https://www.nbcnews.com/news/world/drone-attacks-world-s-largest-oil-processing-site-oil-field-n1054511.

18 Michel, *Counter Drone Systems*.

survived one air-to-air attack as well as two patriot missiles fired at it.[19] Traditional military radars, likewise, only detect larger aircraft as compared to the smaller drone. Besides, because drones are cheaper, it is not viable to take them down with exorbitantly expensive conventional anti-aircraft capabilities.[20]

Contemplating all these issues, states have started adopting dedicated systems to counter the threats posed by drones in both civil and military domains, which are based upon a combination of modern detection and mitigating capabilities.

Multiple state and non-state entities started to research and develop these systems right at the start of the Twenty-first Century. For instance, NATO and RAND Corporation launched two separate studies, in 2003 and 2008 respectively, to find possible solutions to defend against drone threats.[21] Today, hundreds of counter-drone systems by government-owned and private companies are available in the global market. The massive proliferation of drones in both the civil and security sector, as well as existing gaps in aerial defence systems, are the fundamental drivers of the tremendous development of this market. A report by Market Research Future indicates that this market is estimated to reach USD 4,754.2 million from USD 826.4 million with a Composite Annual Growth Rate (CAGR) of 24.7%.[22] There used to

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19 Ilan Ben Zion, "IDF Fails 3 Times to Bring down Drone over Golan," *Times of Israel*, July 17, 2016, http://www.timesofisrael.com/idf-we-tried-and-failed-3-times-to-bring-down-drone-over-golan/.

20 Andrew Liptak, "A US Ally Shot down a $200 Drone with a $3 Million Patriot Missile," *Verge*, March 16, 2017, https://www.theverge.com/2017/3/16/14944256/patriot-missile-shot-down-consumer-drone-us-military.

21 "Counter Drone Systems: Military Sector," DABIN Systems, accessed March 27, 2022, http://www.dabinsystems.com.

22 "Counter-UAS Market by Size, Share, Segments, Trends and Forecast 2027," Market Research Future, February 2021, https://www.marketresearchfuture.com/reports/counter-uas-market-7430.

be only 12 dedicated counter-drone systems available around the globe till 2015.[23] However, since then, data indicates that there are now more than 537 systems available in the market developed by 277 companies around the world in partnership with 38 state entities.[24]

Although, these defence systems are more effective and efficient than the traditional ones, however, they are much more expensive as well.[25] Still many modern militaries are acquiring as well as deploying them and have triggered an arms race in this area at both global and regional levels. This arms race has also hit the South Asian region where India is investing heavily in both offensive and defensive capabilities for drone warfare. This has some serious destabilising effects on regional stability and the strategic environment that is shaped by the conflicting interests of two nuclear neighbours, India and Pakistan. This paper aims at conceptualising modern counter-drone systems, as well as their threat mitigation process and capabilities. It also intends to provide insight about how Indian acquisitions in this sphere are likely to trigger an arms race in South Asia which would have serious consequences for regional stability.

Conceptualising Counter-Drone Systems

Counter-drone systems are a state-of-the-art development in the domain of advanced military technology in the Twenty-first Century. These systems, also known as C-UAV, or C-UAS, are a

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23 Gabriel Carisle Birch, John Clark Griffin and Matthew Kelly Erdman, *UAS Detection Classification and Neutralization: Market Survey 2015*, report (Albuquerque: Sandia National Lab, July 2015), https://doi.org/10.2172/1222445.

24 Michel, *Counter Drone Systems*, 6.

25 Jen Judson, "Pentagon Wants a Cheap, Ground-Launched and Hand-Held Counter-Drone Capability," *Defense News*, May 10, 2021, https://www.defensenews.com/pentagon/2021/05/10/pentagon-wants-cheap-ground-launched-and-handheld-counter-drone-capability/.

combination of sophisticated methods and technologies that enable the effective detection and/or disabling of hostile unmanned aircraft.[26] In an era when drones are becoming a weapon of choice for both states and non-state actors, counter-drone systems can be employed against various threats. During a military conflict, C-UAS can be utilised to defend naval assets, air force bases, ground troops, and military convoys. While during peace times, these can be used to protect sensitive installations, critical infrastructure, large public gatherings, and also for border monitoring purposes.[27] For a better understanding of the working of C-UAS, it is necessary to take the types of hostile drones and the categories of threats posed by them, into consideration.

Types of Drones

There exists no globally recognised definition of drones, and their various types are difficult to discern because of their overlapping roles and characteristics.[28] However, the US DoD has divided drones into various groups based on their size, speed, weight, operating altitude, and speed. These details are given in Table 1:

[26] Michel, *Counter Drone Systems*.
[27] "Tech Area of Interest: Installation Counter Unmanned Aerial Systems (CUAS)," *DefTech*, March 11, 2019, https://deftech.nc.gov/blog/2019/03/11/tech-area-interest-installation-counter-unmanned-aerial-systems-cuas.
[28] M.J. Armitage, *Unmanned Aircraft* (London: Brasseys, 1988).

Table 1: Classification of Drones

UAV Group	Size	Weight Range (lbs)	Speed (knots)	Operating Altitude
Group 1	Small	0-20	100	<1200 Above Ground Level (AGL)
Group 2	Medium	21-55	<250	<3500 AGL
Group 3	Large	<1320	<250	<Flight Level (FL) 180
Group 4	Larger	>1320	Any	<Flight Level (FL) 180
Group 5	Largest	>1320	Any	>FL 180

Source: Paul G. Fahlstrom and Thomas J Gleason, "Classes and Missions of UAVs," in *Introduction to UAV Systems*, 4th ed. (New York: Wiley, 2012), 312, https://www.wiley.com/en-us/Introduction+to+UAV+Systems%2C+4th+Edition-p-9781119978664.

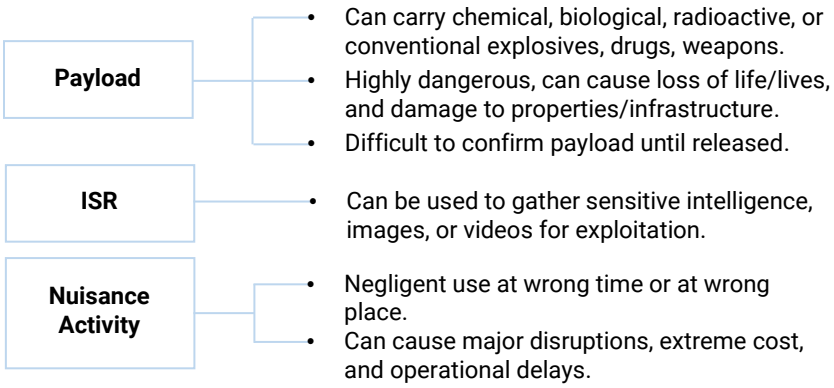
Counter-drone systems face significant challenges in dealing with Group 1 and 2 UAVs listed in Table 1, primarily due to their small size/speed, which makes them difficult to detect and neutralise. Moreover, they are also cheaper and easily available to criminals and non-state entities. These drones can be further categorised into two classes based on their design: Multi-Copter and Fixed-Wing. With low speed and vertical take-off ability, multi-copters are easy to operate and have better manoeuvrability. While fixed-wing drones have more range and fly at higher speed with low manoeuvrability.[29]

[29] Armitage, *Unmanned Aircraft*.

Categories of Threats posed by Drones

The threats posed by drones can be classified into three broader categories: Payload Delivery, ISR, and Nuisance Activity.

Figure 1: Categories of Threats



Source: "C-UAS Factbook, AI-enabled Multi-Mission Solutions," *DroneShield*, accessed March 27, 2022, https://www.droneshield.com/cuas-factbook.

Counter-drone systems must cater to all these threats posed by an individual drone or drone swarms. Drone swarms can be defined as '6 or more drones exhibiting cooperative and/or autonomous behaviour.'[30]Swarming effects are being achieved by integrating AI and Machine Learning (ML) algorithms with the UAS to enhance their efficiency and reach for automated and decentralised missions.[31] Multiple drones coming from various

[30] "Tech Area of Interest: Installation Counter Unmanned Aerial Systems (CUAS)."

[31] Choon Seng Tan, Douglas L. Van Bossuyt and Britta Hale, "System Analysis of Counter-Unmanned Aerial Systems Kill Chain in an Operational Environment," *Systems 9*, no. 4 (December 2021): 79, https://doi.org/10.3390/systems9040079.

directions can pose serious challenges for counter-drone systems to detect and defeat the whole swarm simultaneously.

Counter-Drone System Processing Chain

Countering an unauthorised drone is a multi-stage process that involves real-time coordination between various systems and their operator. The US Department of Homeland Security describes a counter-drone system processing chain as 'a framework for approaching the potential threat posed by the UAS.'[32] This processing chain resembles the US Air Force's general targeting dynamic kill chain, i.e., 'Find, Fix, Track, Target, Engage, and Assess' (F2T2EA),[33] but is less complicated. The steps involved in this processing chain are shown in Figure 2:

Figure 2: Counter-Drone System Processing Chain

Source: Patel and Rizer, "Counter-Unmanned Aircraft Systems Technology Guide," 13.

Detection

First of all, an unauthorised drone needs to be detected by the sensors of a counter-drone system. Following distinct sensors (or their combination) can be used for detection purposes:

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[32] Bhargav Patel and Dmitri Rizer, "Counter-Unmanned Aircraft Systems Technology Guide," (paper, National Urban Security Technology Laboratory, U.S. Department of Homeland Security Science and Technology Directorate, New York, September 2019), https://www.dhs.gov/sites/default/files/publications/c-uas-tech-guide_final_28feb2020.pdf.

[33] "Air Force Doctrine Publication 3-60: Targeting," (U.S. Air Force, November 12, 2021), https://www.doctrine.af.mil/Portals/61/documents/AFDP_3-60/3-60-AFDP-TARGETING.pdf.

Video Detection: Drone attacks can be detected by using high-resolution cameras and securing a visual record of relevant developments. These cameras are largely standard daylight cameras with optical sensors of thermal or infrared imaging. They help provide visualisation of a flying drone and its potential payload. The images gathered can also be used as forensic evidence in prosecution matters.[34] One of its drawbacks is that it cannot be independently used for detection and has high false-alarm rates. Plus, these cameras become highly unreliable in the dark, fog, and other extreme weather conditions.[35]

Audio Detection: Audio detection is also an important method through which unmanned aircraft are detected by C-UAS. A drone produces a specific sound whose frequency can range from 400 hertz (Hz) to 8 kilohertz (kHz). This technique employs numerous microphones which enable identification of the distinct acoustic signature of micro unmanned aircraft. The signal detected is later compared with the information already stored in a database. If more sets of microphones are used, triangulation can take place. This technology can detect every single drone within a near field including those flying without emitting RF emissions. It is also efficient in detecting drones in the ground clutter, which remains undetectable by using other technologies. It is mobile, deployable, as well as passive and can fill gaps in those areas which are usually not detected by other sensors. One of its drawbacks is

[34] Argyrios Georgiou, Peter Masters, Stephen Johnson and Luke Feetham, "UAV-Assisted Real-Time Evidence Detection in Outdoor Crime Scene Investigations," *Journal of Forensic Sciences* 67, no. 3 (2022): 1221-1232, doi:10.1111/1556-4029.15009.

[35] Robin Radar Systems, "10 Counter-Drone Technologies to Detect and Stop Drones Today," accessed March 28, 2022, https://www.robinradar.com/press/blog/10-counter-drone-technologies-to-detect-and-stop-drones-today.

that it cannot work in a noisy environment and has a short range of 300 to 500 metres.[36]

Radio Frequency Detection (RFD): A C-UAS employs a sensor system that locates, identifies, and detects the presence of a nearby unmanned aircraft by matching the frequencies with which that drone operates. The altitude of a drone, the GPS coordinates of both the drone and the pilot handling it, and another unique identifier are identified through RF detection. During the process, one or more antennae are employed to receive radio waves and a processor is used to examine the RF spectrum. The information gathered is used to draw up the conversation between the drone and its handler. Through RF detection the Media Access Control (MAC) addresses can also be detected. As a result of which, drones operated through telecommunication devices or Wi-Fi can also be detected. In addition to acting as an anti-drone system, RFD is also used in prosecution matters, by producing a link between a drone and its controller. By using multiple radio units, some advanced systems can triangulate the drone along with its pilot and detect its possible manoeuvring. It is cost-effective and can identify various drones and their controllers simultaneously. However, some of its drawbacks include at times failure to locate and track drones. As it often fails to detect autonomous drones, it is also not very effective in crowded RF areas and is confined to a short-range.[37]

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[36] Sara Al-Emadi, Abdulla Al-Ali and Abdulaziz Al-Ali, "Audio-Based Drone Detection and Identification Using Deep Learning Techniques with Dataset Enhancement through Generative Adversarial Networks," *Sensors* 21, no. 15 (July 21, 2021): 4953, https://doi.org/10.3390/s21154953.

[37] Huan Lv, Fang Liu and NaiChang Yuan, "Drone Presence Detection by the Drone's RF Communication," *Journal of Physics: Conference Series* 1738, no. 1 (January 1, 2021): 012044, https://doi.org/10.1088/1742-6596/1738/1/012044.

Infrared Detection: Infrared detectors detect the heat signature of a drone produced by its fuel combustion or by its electric circuits. This detection method is suitable for detecting small drones, especially at night-time.[38]

Radar-based Detection: As drones are small, low-flying aircraft, a radar system usually fails to detect them, so if the radar is specifically designed with a high resolution and 3D tracking function, it can successfully detect small-scale drones. It is through radio signatures of small, unmanned aircraft that a C-UAS detects their presence. These radio signatures are produced when the unmanned aircraft comes across the radio frequency waves emitted by the detection device. A C-UAS uses algorithms to detect drones and this professional function enables it to spare other low-flying objects, like birds. This method uses radio energy to detect an object by giving out a signal and then receiving its reflection. By this, the drone detection radar measures the direction, position, and distance of the drone. A radar system does not pick up small objects and its radio signals are mostly designed for larger and faster objects, like aircraft. One of its strengths is its long-range, constant tracking ability, power to detect multiple targets simultaneously. Unlike video detection, it works independently of visual conditions and bad weather. One of its drawbacks is that it is the drone size and speed on which its detection range depends, and at times, it fails to distinguish a drone from a bird which can result in serious accidents.[39]

The majority of counter-drone systems available in the market use multiple detection methods simultaneously — also called Layered

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[38] Petar Andraši, Tomislav Radišić, Mario Muštra and Jurica Ivošević, "Night-Time Detection of UAVs Using Thermal Infrared Camera," *Transportation Research Procedia* 28 (January 1, 2017): 183–90, https://doi.org/10.1016/j.trpro.2017.12.184.

[39] 911 Security, "Radar Drone Detection: Can Drones Be Detected Using a Radar?," accessed March 28, 2022, https://www.911security.com/en-us/knowledge-hub/drone-detection/radar.

Detection Mechanism — for effective detection of threats. The layered approach provides credible detection solutions against an attack launched by drones of different types and specifications. However, it significantly increases the cost of the systems.

Tracking

Multiple detection methods and sensors are used to detect a threat and also provide auxiliary data of the detected drone as well as track its continuously changing location. A track can be defined as 'a compilation of location reports over a period of time.'[40] Tracks can be in the form of quadrant alerts or a heat map display.

Identification

The identification stage includes the classification and assessment of the intent of the detected drone. The system analyses the data and the track provided by the detectors and decides, whether it is a threat or not, with the assistance of the C-UAS operator. However, the integration of AI, big data, and ML with modern counter-drone systems has made them independent of human assistance.[41] After the identification of a threat, the system disseminates the signal to available response options to counter it.

Target Engagement

There are two types of target engagement measures available in counter-drone systems — Kinetic and Non-Kinetic.

[40] Patel and Rizer, "Counter-Unmanned Aircraft Systems Technology Guide."

[41] Tan, Van Bossuyt and Hale, "System Analysis of Counter-Unmanned Aerial Systems Kill Chain in an Operational Environment."

Kinetic Measures: Kinetic measures also called 'hard-kill' options employed to counter hostile drones generally involve some sort of direct physical acts designed to eliminate or lower the incoming threat. These include High Power Microwave (HPM) Devices, High-Energy Lasers, Drone Catchers, and Conventional Ammunition.

HPM devices generate an Electromagnetic Pulse (EMP) that can ultimately lead to the disruption of electronic devices carried by the drone. The electronic circuitry in drones is disrupted and destroyed when the EMP interferes with radio links.[42] There are, however, many risks involved in the use of HPM devices. For instance, their cost is exorbitantly high, and they always run a risk of disrupting other electronic devices in the area where they operate. In some cases, they switch off the drone instantly and make it fall to the ground in an uncontrolled manner, risking lives and damage to properties. However, HMPs are considered to be one of the best options to counter swarm attacks among all other options available in the market.[43]

Another important kinetic counter-measure is the use of High-Energy Lasers. These lasers are high-powered optical devices that generate a focused beam of light carrying high energy, also called laser beams. The laser beam is used to attack the drone for damaging either its structure and/or its electronics, thus rendering it inoperable. One of its benefits is that it can physically stop the drone, but the dangers associated with it outweigh its benefits. On

[42] Shaza Arif, "Chinese EMP Test to Counter Unmanned Aerial Systems – Analysis," *Eurasia Review*, September 25, 2021, https://www.eurasiareview.com/25092021-chinese-emp-test-to-counter-unmanned-aerial-systems-analysis/.

[43] "EMPs Could Combat Vast Drone Swarms Better than Weapons," *Mind Matters*, August 23, 2021, https://mindmatters.ai/2021/08/emps-could-combat-vast-drone-swarms-better-than-weapons/.

the one hand, it is highly expensive and on other hand, the risk of collateral damage may be more.[44]

Drone catchers are popular kinetic measures among civil Law Enforcement Agencies (LEAs) to target and capture an attacking drone. In this system, a hanging net is deployed with a drone, and net cannon fired either from the ground and/or a drone itself is used to entrap the targeting drone. As it physically captures the drone, there is always a low risk of collateral damage associated with it. As these nets are launched from the ground, they are semi-automatic with high precision and accuracy. The range of these catchers can be increased by launching them from another drone. The captured drone can be used to gather information for forensics and prosecution.[45]

Conventional ammunition is also being used to destroy drones in many countries. This includes sniper guns and shotguns to shoot down UAVs, suicidal drones, and artillery shells that burst into the air to destroy and disrupt swarm attacks.[46] These are cheaper options as compared to other sophisticated counter-measures. However, these options are less accurate and need a high degree of skill.

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[44] Philip Butterworth-Hayes, "High Energy Lasers: Almost Ready for Effective Drone Defence on the Battlefield," *Unmanned Airspace*, September 1, 2021, https://www.unmannedairspace.info/counter-uas-systems-and-policies/high-energy-lasers-almost-but-not-quite-ready-for-drone-defence-on-the-battlefield/.

[45] "Pneumatic Powered Drone Catcher Gun: Net Thrower," *Nevon Projects*, November 13, 2020, https://nevonprojects.com/pneumatic-powered-drone-catcher-gun-net-thrower/.

[46] Jen Judson, "Industry Pitches Munitions Designed to Defeat Drones," *Defense News*, September 13, 2017, https://www.defensenews.com/digital-show-dailies/dsei/2017/09/13/how-to-shoot-down-a-drone-industry-pitches-munitions-designed-to-take-them-out/.

Non-Kinetic Measures: The techniques used to interfere with the communication system between a drone and its operator or with its navigation system, in order to make it ineffective, are non-kinetic countermeasures.[47] These measures include jamming, spoofing, and hacking.

'Jamming' is an efficient non-kinetic measure through which electromagnetic noise is blasted at the same radio frequency which is used by the detected drone to operate and send forth information. The drone signal jammer, in addition to recording the private conversation between a drone and its pilot, blocks communications between a drone and the entire command and control system. The goal is usually attained through using an RF jammer which is a handheld device. The device sends a large amount of RF energy toward a suspected drone and blocks the control signal that it receives from its operator. The result of the operation can be one of four possible scenarios: A drone might either fall uncontrolled to the ground or can make a controlled landing in its exact position; it can also fly to a random uncontrolled location and can also return to a user-set home location.[48] Another kind of jamming technique that disrupts a drone's communication link by RF interference that connects it with a navigation satellite, is called 'navigation jamming.' When a drone's satellite link, associated with navigation like GPS and GLONASS,[49] is disrupted, the detected drone gets blind and disabled.[50]

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47 Patel and Rizer, "Counter-Unmanned Aircraft Systems Technology Guide," 23.

48 Shawn Manaher, "Will A Drone Jammer Take Out My Drone? Is It Legal?," *Hobby Nation*, accessed March 28, 2022, https://hobbynation.net/will-a-drone-jammer-take-out-my-drone/.

49 GLONASS means GLObalnayaNAvigatsionnayaSputnikovaya Sistema in Russian. The function of Russia's GLONASS satellite navigation system is analogous to that of several other global satellite positioning systems: the GPS (Global Positioning System) of the

A relatively new non-kinetic measure used to counter drones is 'spoofing.' This measure enables feeding a counterfeit navigation link or communication command to take full control or redirect the targeted drone. A spoofing transmitter radiates a new signal to the drone, which captures it by replacing the earlier communication with the GPS, which it would otherwise use for navigation.[51]

'Hacking' is yet another important method among the non-kinetic measures of counter-drone systems. Different software is used to hijack drones using weak authentication and encryption methods in their communication links. This method enables a hacker to send commands to a targeted drone. Thus, a persistent backdoor established by induced malware allows a hacker to fully control the functions of a drone—be it related to bringing it down to the ground or hijacking it to conduct independent surveillance.[52]

The most important element of any counter-drone system is its command and control setup which keeps its processing chain — from detection to interception — intact. Such a setup involves various hardware as well as software components, and multipurpose screens on which the operations of a counter-drone system can be monitored by an operator. Although AI has revolutionised defence systems, the process of making decisions for countering drone threats has primarily remained in human hands till now.

United States, Europe's Galileo satellite positioning system, and China's BeiDou satellite navigation system.

50 "GPS Spoofing and Jamming: A Viable Defence against Drones?," accessed March 28, 2022, https://www.linkedin.com/pulse/gps-spoofing-jamming-viable-defence-against-drones-guy-buesnel.

51 Ibid.

52 Systems, "10 Counter-Drone Technologies to Detect and Stop Drones Today."

A New Arms Race in South Asia

As technology is getting more sophisticated over time, warfare is becoming even more expensive.[53] Nevertheless, states around the globe are still investing heavily in emerging military technologies to safeguard their national interest. Drone technology is one of the most significant technologies shaping modern warfare. With the advancements discussed earlier, the roles of UAVs will also continue to evolve. According to Jonathan Marcus, a professor at the Strategy and Security Institute at Exeter University, 'The combat drone was once the preserve of military superpowers but no longer. Its use by insurgents and smaller nations is already changing the nature of battle.'[54] Therefore, to secure themselves against drone attacks and to retain their technological edge in this domain, developed states are significantly spending on Research and Development of integrated counter-drone systems rendering a new arms race at both global and regional levels.

Beyond the involvement of nation-states, numerous commercial enterprises and leading technology companies have entered the counter-drone industry, unveiling solutions tailored for both military and civilian applications. Consequently, the competitive dynamics in this field are multifaceted. The first aspect of this competition involves states striving to assert dominance in this sector. The second aspect encompasses a rivalry within the commercial sphere, where drone manufacturers and counter-drone solution providers continually endeavour to outpace each other, aiming to maintain a competitive edge.[55]

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53 Tejvan Pettinger, "Why War Is Becoming More Costly," *Economics Help*, March 11, 2022, https://www.economicshelp.org/blog/167994/economics/why-war-is-becoming-more-costly/.

54 Marcus, "Combat Drones."

55 Steven Melendez, "The Anti-Drone Arms Race Is Taking Off," *Fast Company*, September 21, 2016,

In South Asia, the Indian military's extensive acquisition of counter-drone systems, including both locally developed and imported technologies, has notably intensified the competitive dynamics in the region's defence sector. India's Defence Research and Development Organisation (DRDO), in collaboration with the Bharat Electronics Limited (BEL) and two other private companies, has indigenously developed a counter-drone system D-4 that costs around INR 25 crore apiece.[56] The specifications of D-4 systems are given in Table 2:

Table 2: DRDO's Counter-Drone System

Specifications of D-4 Counter-Drone System	
Country of Origin	India
Capabilities	Detection and Disruption
Detection Range	4 km
Disruption Range	1 – 2.5 km
Coverage	360 Degrees
Detection	EO Radar/ RF /GNSS
Disruption	Jamming and Laser Kill

Source: Javaid, "Explained: What Is an Anti-Drone System Developed by DRDO?"

In response to an alleged drone attack at the Indian Air Force Base Jammu on 27 June 2021, India's Defence Acquisition Council (DAC) approved the procurement of D-4 counter-drone systems for all three services. On 31 August 2021, all three Indian military services signed deals with the DRDO to purchase their D-4

https://www.fastcompany.com/3063250/the-anti-drone-arms-race-is-taking-off.

56 Arfa Javaid, "Explained: What Is an Anti-Drone System Developed by DRDO?," *Jagranjosh.com*, July 29, 2021, https://www.jagranjosh.com/general-knowledge/anti-drone-system-deveoped-by-drdo-to-counter-enemy-drones-1627561929-1.

counter-drone systems.[57] Indian officials told the media, 'All three services Army, Navy, and Air Force have signed a contract with Navratna Defence PSU Bharat Electronics Limited (BEL) for the supply of the first indigenous comprehensive Anti-Drone System with both hard-kill and soft-kill capabilities in New Delhi on 31 August 2021.'[58] After the contract was signed with the DRDO, Indian Armed Forces (IAF) immediately placed orders worth more than INR 300 crore for indigenous counter-drone systems, along with other private companies. For instance, a private Hyderabad-based tech company, Zen Technologies, revealed on 3 September 2021 that the Indian Air Force (IAF) had placed an INR 155 crore contract for counter-drone systems.[59] As per Indian media reports, some of these placed orders were delivered in December 2021.[60]

Apart from procuring the DRDO's counter-drone systems, the Indian Army has also been working with an Israeli firm, *Smart Shooter*, for acquiring their SMASH-2000 systems.[61] The Indian

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57 "After Navy, Indian Army, Air Force Sign Deal with DRDO for Anti-Drone System," *Hindustan Times*, September 4, 2021, https://www.hindustantimes.com/videos/news/after-navy-indian-army-air-force-sign-deal-with-drdo-for-anti-drone-system-101630695004009.html.

58 Manjeet Negi, "Indian Army, Navy, Air Force Sign Deal for Inducting DRDO-Developed Anti-Drone System," *India Today*, September 4, 2021, https://www.indiatoday.in/india/story/indian-army-navy-air-force-sign-deal-inducting-drdo-developed-anti-drone-system-1849097-2021-09-04.

59 "Zen Technologies Bags Rs 155 Cr Anti-Drone System Contract from IAF," *Business Today*, accessed March 29, 2022, https://www.businesstoday.in/latest/corporate/story/zen-technologies-bags-rs-155-cr-anti-drone-system-contract-from-iaf-305817-2021-09-03.

60 Rahul Singh, "Armed Forces Get New Anti-Airfield Weapon, Counter-Drone Systems," *Hindustan Times*, December 14, 2021, https://www.hindustantimes.com/india-news/armed-forces-get-new-anti-airfield-weapon-counter-drone-systems-101639492104798.html.

61 Haider Abbas, "SMASH-2000: Israel's Another Game-Changing Weapon for Indian Troops to Check-Mate Chinese, Turkish Drones?,"

Navy has already placed an order for an unspecified quantity of SMASH-2000 rifle-mounted systems from the same company.[62] The cost of one unit of SMASH-2000 Fire Control System (FAC) for a single assault rifle is around INR 1 million.[63] The Indian Navy has also signed a contract with Bharat Electronics Limited (BEL) for the development of the 'Naval Anti-Drone System (NADS)'.[64]

Along with the acquisition of these counter-drone systems, India's military is also spending an enormous budget to purchase offensive drone capabilities. India will purchase 30 advanced Predator drones from the US that can fire missiles at any target in sea, air, or ground with pinpoint accuracy. In 2022, Indian media reported that 'The discussions on the sale of 30 Predator armed

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Eurasian Times, December 12, 2020, https://eurasiantimes.com/israel-equips-indian-army-with-another-game-changing-weapon-amid-flaring-tensions-with-pakistan-china/; Anupama Ghosh, "India Could Fast-Track Israeli SMASH 2000 Plus Anti-Drone Systems to Thwart Jammu-Like Attacks?" *Eurasian Times,* June 29, 2021, https://www.eurasiantimes.com/india-could-fast-track-israeli-smash-2000-plus-anti-drone-systems-to-thwart-jammu-like-attacks/.

62 "Navy Orders Israeli SMASH 2000 Plus Systems to Tackle Drones, More Contracts in Offing," *Print*, December 8, 2020, https://theprint.in/defence/navy-orders-israeli-smash-2000-plus-systems-to-tackle-drones-more-contracts-in-offing/562955/.

63 "Indian Navy Orders Israeli Smash 2000 Plus Systems to Counter Threat from Small Drones," *Latestly*, December 9, 2020, https://www.latestly.com/india/news/indian-navy-orders-israeli-smash-2000-plus-systems-to-counter-threat-from-small-drones-2188965.html.

64 "Navy Signs Contract with BEL to Procure India's First Indigenous Naval Anti-Drone System," *Print*, August 31, 2021, https://theprint.in/defence/navy-signs-contract-with-bel-to-procure-indias-first-indigenous-naval-anti-drone-system/725726/.

drones by the US to India, the first to a non-NATO ally, at an estimated cost of USD3 billion, is at an advanced stage.'[65]

Furthermore, the Indian Army has placed an order to buy 100 swarming drone systems that can attack and hit military targets with 5-6 kg explosive devices.[66] Likewise, it has also acquired 'Smart Anti-Airfield Weapons (SAAWs) that can target enemy airfield assets such as radars, bunkers, taxiways, and runways.'[67]

As India is always trying to find space for limited armed conflict with Pakistan, the combination of offensive and defensive drone capabilities along with supersonic/hypersonic missiles in her arsenal would provide the Indian military with another choice of weapons (especially drone swarms) in case of any future conflict. In this scenario, the extensive acquisitions by India have a destabilizing effect, carrying significant implications for escalating conflicts and undermining crisis stability. The advancement of India's military capabilities has compelled Pakistan into a continuous cycle of defence enhancement, leaving it with little choice but to acquire similar capabilities in order to maintain its conventional deterrence.

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65 Shishir Gupta, "Plan to Buy Predator Drones Put on Hold," *Hindustan Times*, February 23, 2022, https://www.hindustantimes.com/india-news/plan-to-buy-predator-drones-put-on-hold-101645565612604.html. *Editor's Note:* During the finalisation of this paper, it was reported in April 2023, that the Indian Armed Forces cut down their requirement for the acquisition of US MQ-9B Predator high altitude long endurance (HALE) armed drones from 30 to 18 platforms - six each of the Indian Army, Navy, and the Air Force.

66 "Army Orders 100 Swarm Drones Under Emergency Procurement," *NDTV.com*, accessed March 29, 2022, https://www.ndtv.com/india-news/indian-army-orders-100-swarm-drones-under-emergency-procurement-2529085.

67 Rahul Singh, "Armed Forces Get New Anti-Airfield Weapon, Counter-Drone Systems," *Hindustan Times*, December 14, 2021, https://www.hindustantimes.com/india-news/armed-forces-get-new-anti-airfield-weapon-counter-drone-systems-101639492104798.html.

Conclusion

Technological evolution is profoundly reshaping both the tools and strategies of warfare. This evolution is particularly evident in the continual advancement of drones and counter-drone systems, which are set to significantly influence, if not dominate, future battlefields. The Nagorno-Karabakh conflict between Azerbaijan and Armenia, as well as the ongoing war between Russia and Ukraine, exemplify the critical role of drones in various facets of warfare, underscoring their growing importance across all levels of military engagement.

However, the strategic landscape of South Asia is markedly different and more precarious compared to other global regions. Even minor errors in judgment or misconceptions regarding an adversary's capabilities could plunge the entire region into conflict. The acquisition of advanced weaponry by India, a state which previously 'mistakenly' launched a supersonic missile into Pakistani territory, poses a significant threat not only to the stability of arms development but also to the broader crisis and strategic stability of South Asia. Furthermore, US support and provision of cutting-edge weapons and intelligence to India, as part of various strategic agreements aimed at countering China's regional influence, exacerbates the situation. Consequently, South Asia continues to be adversely affected by the lack of an effective arms control framework and the broader context of global power rivalry.

Abdullah Rehman Butt holds an MPhil degree in Strategic and Nuclear Studies from the National Defence University (NDU), Islamabad, Pakistan. His areas of research include Space, UAVs, Warfare, and Strategic Stability Issues in South Asia.