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Future Prospects of Drone Swarm Systems

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Introduction to Swarming

In the course of military history, swarming has played a role in a variety of conflicts, ranging from the sweeping campaigns of horse archer armies on the Eurasian steppe to more contemporary engagements waged between light infantry rebels and conventional opponents. It has been used at the operational and tactical levels, for defensive and offensive purposes, by conventional and unconventional forces, on land, sea, and air.¹ The future battlefield will be comparatively barren as military activities spread out. This is because of the rising potency of weaponry, especially precision-guided munitions, which pose a threat to battlefield concentrations of mass. Due to recent advancements in command and control and sensor technology, long-range fires may be delivered in several ways. Even a direct hit is more likely to cause death. Combat increasingly resembles a game of hide-and-seek, in which individual troops must avoid detection to prevail.

Swarming may be planned or spontaneous. Units often swarm in a pattern known as "pulsing"² in which they swiftly focus on a target, assault, and then disperse again. A collection of drones that cooperate and fly as a flock to achieve a certain objective is referred to as a "drone swarm." SWARM stands for "Smart Warfighting Array of Reconfigurable Modules".³

Now, the objectives are different, and there are varied uses in both civilian and military contexts. It may be used to map or survey enormous regions in a very short amount of time, producing information that is essential for a variety of purposes including military operations, Environmental mapping, utility inspection, and more. Drones used by the military may also be used as hovering weapons with a single mission i.e., to destroy an enemy target. The drone swarm system may be

¹ Edwards, Sean J. A. "Swarming and the Future of Warfare." RAND Corporation, May 16, 2005. https://www.rand.org/pubs/rgs_dissertations/RGSD189.html.

² Ibid.

³ K, Col Ashokan. "Swarms - Futuristic Air Defence & Electronic Warfare." SWARMS - FUTURISTIC AIR DEFENCE & ELECTRONIC WARFARE - Olive Greens Institute Blog- Olive Greens Institute SSB | NDA | CDS. <https://www.olivegreens.co.in/blog/swarms-futuristic-air-defence-electronic-warfare>.

operated remotely, or it can fly itself using automation algorithms programmed into it which will be further elaborated on in the paper.

There has been an increased interest in swarm technology over the last few years. Since 2015, the United States has conducted trials of drone swarming. In January 2017⁴, the United States Strategic Capabilities Office and Air Force conducted trials with 103 "Perdix Quadcopter Drones." Another example of a swarm display was in December 2017, when a swarm of 1,108 drones was shown for the first time at the Global Fortune Forum in Guangzhou - for entertainment purposes.⁵ The fast-evolving state of unmanned systems technology in both the public and corporate sectors is largely responsible for this. Compared to manned systems, unmanned systems offer numerous advantages. UAVs need far less time and money to operate. Manned missions are useful in unforeseen circumstances. They help maintain the trust of the public. They are best used for surveillance, close air support, and certain attack missions. Manned fighter jets are best for establishing air dominance.⁶ The use of mobile warfare has become more prevalent in modern armies. Swarming would be the next step forward in the development of warfare at this point, with the swarms displaying the decentralised character of physical combat in addition to the mobility of manoeuvre warfare.

⁴ (ret'd), Lt Gen Balli Pawar. "Drone Swarm Technology and Its Impact on Future Warfare." The Daily Guardian, May 15, 2020. <https://theguardian.com/drone-swarm-technology-and-its-impact-on-future-warfare/>.

⁵ (ret'd), Lt Gen Balli Pawar. "Drone Swarm Technology and Its Impact on Future Warfare." The Daily Guardian, May 15, 2020. <https://theguardian.com/drone-swarm-technology-and-its-impact-on-future-warfare/>.

⁶ "Manned vs Unmanned." SP's Aviation - Civil Aviation. Accessed November 7, 2022. <https://www.sps-aviation.com/story/?id=1278>.

How Drone Swarm Systems Work

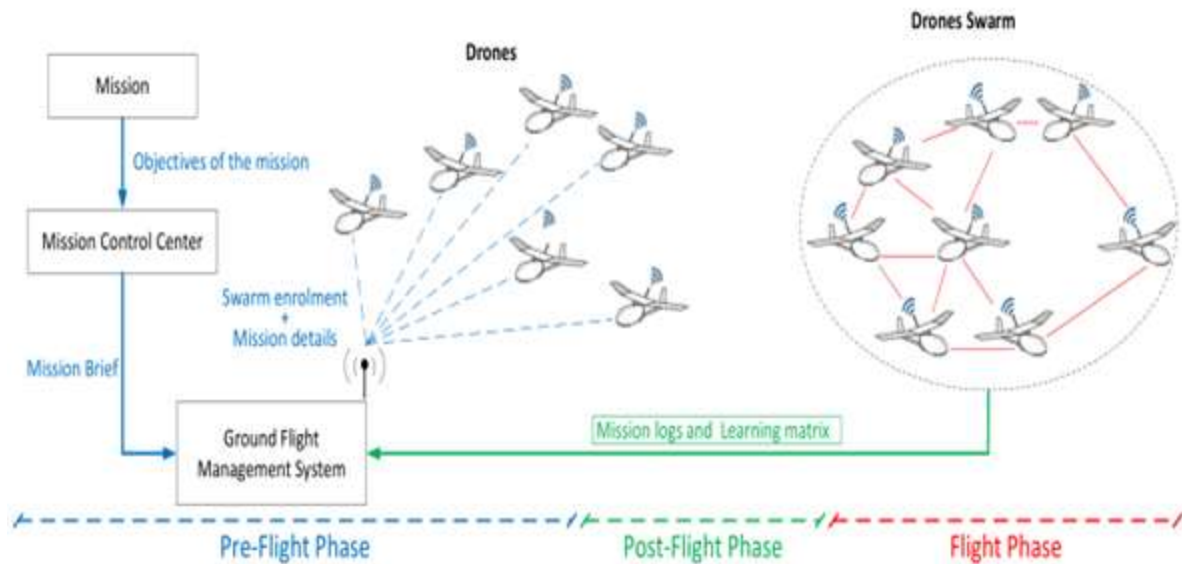


Image Credits: ResearchGate

There are Four types of communication with drones⁷: Drone to Drone (D2D), Drone to Ground Station (D2GS), Drone to Network (D2N), and Drone to Satellite (D2S). There are two main types of this technology: Manual and Automatic drone swarm systems⁸. In a manual system, monitoring and controlling the drones requires the employment of a control centre or a remote controller device. Drones are fitted with an autonomous system that enables them to adjust based on complex algorithms. The figure above depicts the two most crucial elements of the manual drone swarm system, including drone swarms in the air and a control centre on the ground. real-time communication between the drones and the control centre is essential. Voice and text channels are two ways that drones on the ground and in the air may communicate with one another. Large swarms need a completely dispersed communication system that grows effectively and enhances

⁷ “Security Analysis of a Swarm of Drones Resisting Attacks ... - Ceur-Ws.org.” Accessed November 7, 2022. <http://ceur-ws.org/Vol-2914/paper28.pdf>.

⁸ “RF Wireless World.” How Drone Swarm System Works | What is Drone Swarm? <https://www.rfwireless-world.com/Terminology/How-Drone-Swarm-System-Works.html>.

"many-to-many" communication. A drone swarm is a floating wireless mesh network. An AI-based automated target recognition function makes it possible for drones to identify targets automatically – including people, weapons, vehicles, and tanks⁹. This information is shown on the screen of the control station. As a result, it is less likely that the operator will miss a target and it will be simpler for a proper weapon platform to engage the target.

One GCS (Ground Control Station) can frequently handle UAV swarm management, minimising deployment and equipment needs. To eliminate the need for a single operator to handle several drones simultaneously, the drones will primarily operate independently.

In an autonomous system, each drone is given a different set of instructions on the flight path that it should follow. One of the fundamental principles of this system is that all of the drones that make up a flock would, on average, fly in the same direction and stay in the same approximate location. In some cases, like those of drone swarms without a camera, there is a bigger drone leading them. The algorithm that was developed for each drone in the system and the messages they get from other drones allow the participating drones to self-organize. Based on the communication they receive while in flight, they are capable of making autonomous adjustments to changing conditions. They can exhibit swarming behaviour in this way, which is comparable to that of insects or birds. However, due to the rapid development of artificial intelligence and machine learning algorithms, they will no longer require human control and instead be capable of making their judgments.

Advantages and Future of Swarm Drones

Human lives are irreplaceable yet drones and swarms of drones are very affordable and disposable. The military relies heavily on risk management, which is used in part to identify and eliminate threats to people. Drone use may help reduce the strategic and political risk caused by rising death

⁹ "RF Wireless World." How Drone Swarm System Works | What is Drone Swarm? <https://www.rfwireless-world.com/Terminology/How-Drone-Swarm-System-Works.html>.

tolls. Contrarily, drone swarms may improve responsible risk-taking at the operational level. For instance, a human-operated drone cannot give the level of detail that a swarm of drones can while monitoring earthquake-affected areas or structures considered unsuitable for humans. Drone swarms have advantages in offensive, mass, manoeuvre, economy of force, security, and surprise due to their speed, pervasiveness, and prevalence.¹⁰

Drone swarms also lessen the financial burden of conflict. The F-16, the US Air Force's cheapest fighter, costs \$18 million without accounting for either the cost of educating pilots or the cost of maintaining aircraft. In thirty years, the US Navy will spend \$509 billion to construct 308 ships.¹¹ The average cost of sending a single military man to Afghanistan in 2014 was \$2,1,000,000. The cost of using a drone is much lower. With an average cost of \$600, a drone swarm of 1000 drones, as proposed by the US Navy, would still be 97% cheaper than a single F-16 fighter jet.

The use of swarms provides a novel way to overcome conventional nuclear delivery systems, which is a benefit for the defence. Innovative missile defences, maybe even against hypersonic missiles, might be implemented using these systems. Any approaching missile, regardless of how quick or agile it is, has a high probability of hitting a drone (whether lightweight drones are enough to damage a re-entry vehicle or throw it off course is an open question). These same drones might also be used to great effect as air mines, either by crashing into approaching bombers or detonating themselves in their proximity. Even very tiny drones have the potential to cause considerable damage to aircraft wings. Because there is less airspace for defenders to cover and because they can utilise drones with a shorter range, this might be particularly useful against bombers flying at a low altitude. Last but not least, multi-domain swarms of underwater, surface, and/or airborne drones would be able to scan the seas for enemy submarines. The drones might identify the submarines, track them, provide information about them, or even strike them. In addition to this, they may get information from more extensive sensor networks.

¹⁰ Sanders, Andrew W., and US Army School for Advanced Military Studies Fort Leavenworth United States. "Drone Swarms." DTIC. <https://apps.dtic.mil/sti/citations/AD1039921>.

¹¹ Sandzrs, Andrew W., and US Army School for Advanced Military Studies Fort Leavenworth United States. "Drone Swarms." DTIC. <https://apps.dtic.mil/sti/citations/AD1039921>.

A drone swarm may conduct offensive operations such as a kinetic assault or an attack via cyber warfare tools. It will be able to influence a large number of adversary targets, targeting them where they are most vulnerable. By behaving in a distracted way, it will slow down the response time of the defence.¹² Even if seven of the drones that are attacking a target at the same time are destroyed, the other three will still be able to complete their objective. Even a big swarm of drones should be more efficient and cheaper to operate in the future than a single human or unmanned aircraft.

Swarms may potentially make nuclear targeting more accurate. Data could be gathered with the usage of drones, which can then be utilised to determine previously undisclosed defences or weaknesses. Traditional delivery systems such as cruise missiles, even if they are not technically drones, may use drone swarm technology to alter their approach while they are in transit. This may be done depending on the success or failure of other systems in hitting targets. This is particularly helpful for counterforce operations, which need accurate and thorough target identification as well as precision strikes on certain targets to be successful. When it comes to second strikes and counter-value attacks, which are directed against cities and populations, improved targeting is less critical. In addition, the need for fewer warheads and delivery systems would be reduced if the weapons were more precise. The cost of maintenance and maybe other expenditures might be reduced if improvements were targeted.

Swarms of drones will be very helpful for launching strikes that result in many casualties. For countries without nuclear weapons, these weapons might serve as a strategic deterrent, and in the hands of terrorists, they could be deadly murder tools. In 2018, two unmanned drones were sent to the residence of Venezuelan Prime Minister Nicolas Maduro¹³. Even though he was able to get away, the assault serves to highlight the usefulness of drone swarms. The result might have been different if the assassins had instead launched twenty drones.

¹² “Factors Determining a Drone Swarm Employment in Military Operations.”. https://www.researchgate.net/publication/352135309_Factors_Determining_a_Drone_Swarm_Employment_in_Military_Operations.

¹³ Atherton, Kelsey. “An Explosion in Venezuela Brings Gimmick Drones to the Political Battlefield.” C4ISRNet. C4ISRNet, August 17, 2022. <https://www.c4isrnet.com/unmanned/2018/08/07/a-drone-explosion-in-venezuela-brings-gimmick-drones-to-the-political-battlefield/>.

Drone swarm networking may benefit from 5G technology's potential beamforming connections for reliable packet delivery with low power consumption and no data loss. 5G offers a dependable and efficient wireless communication network in the sky. Fast cellular connectivity between the ground station and the drones is a big plus for drone swarms. Since video recording and surveillance are common applications for drones, this necessitates a high volume of data transfer. The limited connections made possible by 5G and Wi-Fi 6 allow for accurate motions and instantaneous First-person view responses from UAV operators. As an added benefit, rapid data transfer rates make it possible to see live videos instantly.¹⁴

India's Stand on Drone Swarms

As for India, At the Army Day 2021 ceremony in Delhi on January 15, the Indian Army demonstrated drone swarm technology with seventy-five drones performing a variety of duties, including offensive operations, all created and developed in India. Even though it is not a huge step, it shows that the Indian military is considering making a change, and also because of the ongoing stand-off with China at the LAC, the army has implemented a thorough revamp in its tactics and Order of Battle, in which drone swarms now play a vital role in monitoring the situation on the borders. The Indian army has launched a new project called Project “Zorawar”, it has been implementing cutting-edge technology including swarm drones, loitering munitions, and anti-drone systems as part of its modernization strategy. Swarm drones and anti-drone systems will be jointly developed by the US and India under the Defence Technology Trade Initiative (DTTI)¹⁵, a key milestone that will enable experts from both nations to exchange expertise.

¹⁴ Khan, Haider Ali. “The Combination of 5G and AI Will Unlock New Possibilities for Drone Technology'.” mint, December 7, 2021. <https://www.livemint.com/technology/the-combination-of-5g-and-ai-will-unlock-new-possibilities-for-drone-technology-qualcomm-india-11638785027141.html>.

¹⁵ Staff, India Global Business. “India in the Age of Swarm Drones.” India Global Business. Accessed November 7, 2022. <https://www.indiaglobalbusiness.com/analyses/snap-analysis/india-in-the-age-of-swarm-drones>.

By placing an order with Indian start-ups for INR 200 crore¹⁶ to offer a system that is capable of surveillance, electronic warfare, and kinetic assault, the army has gained the lead in swarm drones. The contract has been awarded to the Bengaluru-based start-up NewSpace Research and Tech. Together with Hindustan Aeronautics Limited, NewSpace Research is developing the next-generation air-launched swarm drone system, the Combat Air Teaming System (CATS).

The Iranian Drone Swarming Strategy

Neither Russia nor Ukraine benefits from the conflict in Ukraine from a foreign policy or national security standpoint. It is Iran. Iran's national interests will be strengthened regardless of whether Russia is successful in its war against Ukraine, because of this warming alliance.

Iran has been a part of the drone system for a while now and in the conflict between Russia and Ukraine. At its core, Iran's Shahed 136 missile drone swarm is a loitering munition meant to destroy distant ground targets. The drones are designed to avoid detection by air defences and overwhelm ground targets by launching in large numbers (in stacks of five and down) before their systems are depleted during the strike run. In December 2021, a video that had been made public made the drone's identity known. These drones have been referred to as "suicide drones" or "kamikaze drones" by Iran. This indicates that they fly into a target and explode. They can be used to attack weapon caches or anti-air defence installations in the United States or Europe. This would be inexpensive for the Russians. Instead of hypersonic missiles, which cost around \$10 million, these Shahed 136 Drones might be a smarter choice as the cost of one Shahed 136 drone is around US\$20,000 (£17,800).¹⁷ Nearly 50 of these would cost less than a million dollars and could be sufficient to accomplish the objective¹⁸. And they have the upper hand against state-of-the-art

¹⁶ "Swarm Drones: A New Frontier for Military Combat." Grant Thornton Bharat. Accessed November 7, 2022. <https://www.granthornton.in/insights/blogs/swarm-drones-a-new-frontier-for-military-combat/#:~:text=With%20a%20display%20of%201%2C000,drone%20displays%20in%20the%20past>.

¹⁷ Dominika Kunertova Senior Researcher. "Ukraine War: Iranian 'Kamikaze' Drones Can Inflict Serious Damage but Will Not Be a Gamechanger." The Conversation, October 19, 2022. [https://theconversation.com/ukraine-war-iranian-kamikaze-drones-can-inflict-serious-damage-but-will-not-be-a-gamechanger-192754#:~:text=But%20TB2s%20are%20expensive%20-%20about,%2420%2C000%20\(%2417%2C800\)%20each](https://theconversation.com/ukraine-war-iranian-kamikaze-drones-can-inflict-serious-damage-but-will-not-be-a-gamechanger-192754#:~:text=But%20TB2s%20are%20expensive%20-%20about,%2420%2C000%20(%2417%2C800)%20each).

¹⁸ Satam, Parth. "Designed to Fight USSR, US Could Arm Ukraine with 'Once Mighty' Hawk Missile System to Challenge Russia." Latest Asian, Middle-East, EurAsian, Indian News, October 26, 2022. <https://eurasianimes.com/signed-to-fight-ussr-us-could-now-arm-ukraine-hawk/>.

surface-to-air missile systems like the S-300, Buk, or Osa, which are designed to take out advanced drones. It was reported by Eurasian Times that Russia may acquire the much more sophisticated Arash-2 drone. There will probably be a rise in interest in drone swarms from nations and terrorist groups as news about their efficacy in Ukraine increases.

Technologies Countering Drone Swarms

To keep up with the rapid pace at which threats like drone swarms are being developed for commercial use, defensive technology to counter them must also advance at breakneck speed. Detect, Identify, and Defeat are the three pillars upon which Lockheed Martin, a U.S.-based aerospace and defence company rests. They claim there are several methods to deal with a drone swarm, including Responding with a Laser, Cybertechnology, and their very own MORFIUS system¹⁹. To counter these threats, Lockheed Martin has collaborated with various services to create and test MORFIUS, a reusable, high-power microwave-based interceptor suitable for Counter-Unmanned Aerial Systems (C-UAS) and C-swarm situations.

As the number of drones in the sky continues to rise, precautions must be taken to protect against any potential problems that might arise as a consequence of cyberattacks and hackers. The number of attacks will continue to rise and to defend these systems effectively, both the manufacturers and the governments will need to work together. It is important to strengthen the degree of security of the drone software against external intrusion to guarantee the well-being of these devices and the people who use them in a civilian context.

In the case of Ukraine and the strikes from Russia with the Shahed 136 drones, they are easy to shoot down because they are low flying and slow, flying at a maximum speed of 185 km/hr. The Ukrainian Territorial Defence Forces have a host of weaponry to bring down the drones, including MiG-29 jets, C-300 cruise missiles, Nasams ground defence systems (Provided by Germany to

¹⁹ “Technology That Counters Drone Swarms.” Lockheed Martin, October 3, 2018. <https://www.lockheedmartin.com/en-us/news/features/2016/webt-laser-swarms-drones.html>.

Ukraine) and small-arms fire. By mid-2023, Ukraine is expected to receive the “Vampire Anti-air defence system” from the USA.

A tweet²⁰ by Ukraine Territorial Defence Forces states– “ We are protecting our civilians from Russian missiles and **drones**. The "**Shahed**" attack **drone** causes significant damage, but it is possible to shoot it down with small arms. The best shooters of the 251 TDF battalion are on duty around the clock to track down and destroy them.”

Conclusion

Swarming, although still in its early phases of study and experimental application, has the potential to significantly alter the character of conflict in the decades to come. Due to the technical difficulty and high cost of the requisite knowledge, swarming will likely be the exclusive domain of major military powers. This is because the swarm's ability to ensure semi and reactive monitoring over a large area gives them a significant advantage over both regular forces lacking analogous capabilities and against insurgents. Drone swarms that use various frequencies to avoid being jammed are one example, as are swarms that can block or eliminate many threats at once, faster than the human brain can comprehend. When faced with cheap drones such as the Shahed or the Orlan, relying on a missile-based air defence system proves to be too expensive. As a result, such countries investigate the use of dedicated surface-to-air anti-aircraft guns (such as the Gepard SPAAGs given by Germany to Ukraine to shoot down Shahed 136 drones) and medium-calibre cannon systems, which can shoot down drones more effectively and cheaply. Drone swarms will become more common as technology improves. There will be a need for understanding the implementation of swarm defences as more countries and non-state actors explore incorporating swarms into their military arsenal. Similar to Turkey's provision of Bayraktar's TB2 drones to the Ukrainian military, Iran's involvement in the war implies a more significant geopolitical shift. Since drone technology has grown more accessible and affordable, a plethora of ambitious players has entered the market, reaping financial and geopolitical benefits. The future is fraught with

²⁰ Forces, Ukraine Territorial Defense. “We Are Protecting Our Civilians from Russian Missiles and Drones. .” Twitter. Twitter, November 2, 2022. https://twitter.com/TDF_UA/status/1587709373043904512.

unpredictability, and to effect changes to the existing swarms, it may be necessary to conduct modelling and simulation, as well as exercises and wargames, using both real and synthetic settings. The swarming drone age has barely started. This indicates that the military will need to make a concerted effort to carefully consider how to design and construct the most effective drone swarms to accomplish their mission objectives.

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