

Swarm Drones

Attacker's Delight, Defender's Nightmare

A Status Report



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A Word from the Author

Ever since the emergence of the unmanned phenomenon, the warfare has never been the same. Starting from their very humble beginnings of giving the war-fighter the marginally incremental capability to 'look around the corner and over the hill' the Unmanned Aerial Systems (UAS) have come to impact every dimension of war fighting today.

Slowly growing wings from their initial 'look-see' avatar, the UAS have earned for themselves, an awesome recognition that goes by the trio of words –'dull, dirty and dangerous'. This is in acceptance of their deadly combat virtues of all-terrain all-mission capability, phenomenal endurance stretching from hours to days to weeks to months and a payload capability that will give a run for their money to the manned platforms - all this with no crew fatalities, no combat fatigue and no 'motivation blues'.

The UAS did not stop at dull, dirty, dangerous, these machines geared up into a deadly combination called 'Manned and Unmanned Teaming' or MUMT for short. MUMT ushered a paradigm qualitative enhancement in the capability of the air warrior as it combined the intellect, intuition, decision making capability and tolerance for ambiguity of the combat pilot with the deadly target acquisition and kill capability of the UAS.

As MUMT was climbing new highs, came another manifestation of the UAS. This time inspired by the awesome power and intelligence of the deadly locust swarms capable of eating away hundreds of acres of standing crops in a matter of minutes as the humans watch in helplessness and amazement.

Much like the deadly insect swarm, the drones configured as swarms (called swarm drones) are lethal machines. Coming in large numbers duly guided by the niche technologies of precise navigation, swarm drones can simply overwhelm any known air defences on ground sea and air and press home a deadly attack.

Thanks to the enabling tools of artificial intelligence, the swarm drones gridded as a formidable net of 'air warriors', possess a mind of their own by which they can pick and choose their targets and kill by precision besides enjoying a degree of survivability against a few of them getting shot down.

Battle baptised on 05 Jan 2018, which is the date that marks the first recorded swarm drone attack on a Russian Air and Naval base in Western Syria, swarm drones showed that day what they can do to land an attack on the air base despite all the air defence power of the mighty Russian SAMs.

The world again witnessed in amazement when on 14 Sep 2019, a small group of Kamikaze drones successfully struck at the Suadi oil facility, despite all the air defences deployed to protect it. The effect was colossal. The attack stalled a whopping 5.7 million barrels of oil and reduced the nation's output to half! The story has just began....

Lake in all matters of 'air attack' and 'air defence', even this one is tied to the eternal 'cause-effect cycle'. True to the dictum 'for every sword a shield,' it simply means that if swarm drones are an unprecedented threat today, suitable air defence means to defeat it will be there tomorrow.

That said, the defenders are fully aware what they are facing. They know that swarm drones will indeed be unstoppable by any of the means that they have in their conventional arsenal. The effort therefore is to devise unconventional means to deal with the new monster.

Efforts are on to find suitable means to detect the swarm drones well in time and kill them en-masse before these can release their lethal loads. Research is on to come out with several variations of soft-kill methods. The world at large is however at the 'baby steps' stage today in this field.

This Subject Brief looks at swarm drones from both sides of the fence, i.e from the attackers' perspective, as well as, from the defender's perspective. For the former, it examines how the swarm drones present a growing lethality today, while for the latter, it tells the story of the defenders and how they are measuring up to brace with the new threat.

Accordingly, the Status Report is composed of two articles as under:-

From Attacker's Perspective

Drone Swarms -a Growing Lethality....*Where is the World? Where are We?*

From Defender's Perspective

Drone Swarms: Bracing up With the New Threat

Drone Swarms -a Growing Lethality...

Where is the World? Where are We?

The credit of using the unmanned platform for the first time goes to Austria, when in 1849 it attacked the Italian city of Venice using unmanned balloons loaded with explosives¹. Surely, the Austrian warriors could have never imagined that this humble beginning of theirs would explode into such a revolution one day, that it would dwarf everything else in the aerial warfare domain. The ‘unmanned revolution’ is upon us for decades now!

Starting from very humble beginnings of little unmanned platforms capable of looking ‘over the hill’ or ‘round the corner’, the combat potential of unmanned vehicles has soared exponentially over time to earn the distinction of being called the ‘dull’, ‘dirty’ and ‘dangerous’. Armed to the teeth, having phenomenal endurance, capable of all-weather and all-terrain operations, no crew fatigue, no lack of motivation, no loss of pilot life.... the unmanned platforms have risen like a sphinx.

As the years rolled, two specific battle functions branched out of the unmanned platforms. One was the teaming of the manned and the unmanned in joint missions. Here the unmanned platforms stood shoulder-to-shoulder with the combat pilot, ‘looking around’ to produce a paradigm enhancement in his situational awareness and increasing his strike potential by many notches in taking on targets, either as assigned or suo moto (latter attracting much ethical criticism- machine over man!)

The other function emerged as the artificial intelligence (AI) became more and more robust so as to be able to weaponise combat platforms. What gradually emerged were the ‘drone swarms’ where hundreds of small unmanned machines were programmed to take on a target, much like the deadly swarm of locust that can menacingly destroy hundreds and thousands square yards of standing crop in a matter of minutes... beyond the control of humans or their machines.

Ironically, it was only a few days back, when the world saw the heart-shaking headlines announcing alarmingly that ‘locust swarms, some three times the size of New York city are eating their way across two Continents, threatening famine in Africa, Middle East and the Indian subcontinent².

This article presents the ‘drone swarm’ scene both at the world stage, as well as, at the Indian doorstep.



Locust swarm – The inspiration for swarm drones.

<https://www.google.com/search?q=locust+swarm+three+times+thesize+of+new+york+city>

What is a SWARM?

SWARM is an acronym which stands for Smart War fighting Array of Reconfigurable Modules. In the language of the Unmanned Aerial Systems (UAS), a swarm would refer to a body of a varying number of small autonomous vehicles which are gridded together to act as one whole (much like the locust swarm). Technology today allows such swarms to fly together based on their own pre-fed intelligence and without any dependence on the traditional ground control station.

A Possible SWARM Task Sheet

This body can be tailor made to produce the end results which could take any of the following forms and more:-

1. Positioned over the area of interest and so programmed as to deliver uninterrupted and continuous information about the designated area. This role in UAS parlance is called Gorgon Stare (Gorgons were three sisters in ancient Greek mythology whose gaze was so ‘grim dreadful and unblinking’ that it could turn a person into a stone!).

Actually each sensor on board the UAS in the swarm will produce its own output. Technology allows the fusion of inputs from multiple sensors into one comprehensive picture shown to the user who has every control over shaping the output, with respect to sensor pan/tilt, range, field of view, altitude, resolution, selective area -zoom etc.



Flocking algorithms in birds and intelligence of a swarm have guided drone swarms

<https://www.google.com/search?q=autonomous+swarms+moving+as+migrating+birds>

2. UASs gridded as swarms actually rely upon each other as migrating birds. They complement one another in group and adhere to the body of rules that is built into them through tools of AI. These rules can be so configured as to produce different shades and levels of intelligence in the vehicles allowing them to perform many different tasks as desired by the user . Some of these could include:-
 - a. Navigate quietly and precisely through restricted spaces (doors windows, bottlenecks, galleries, difficult terrain etc.), 'peep through', collect and send user-demanded information in real-time on audio/video/data etc.
 - b. Carry out a 'keep watch' role duly placed at a user-selected location and report continuously. In this role, the machines could be fed with the 'default threshold' of data related to the area under watch. Any gradual/sudden increase in activity can be picked up and analysed by the user for what it is worth.
 - c. Select targets based on pre-fed information and fire on them as programmed or fire at opportunity targets on user command.
3. The machines in the swarm, based on the intelligence built into them develop a degree of survivability as individual vehicles recognise their identity as a 'body of gridded vehicles'. In such a grid if a vehicle(s) gets knocked down or cannot keep station due to some malfunction, the grid quickly re-adjusts and re-configures respective positions so to fill the gap created. Much like a body of warriors that continues to advance/fight even if a soldier(s) gets knocked down from the group.

Swarms in Action-World Scene

The First Swarm attack in History Happens...

The date of 05 Jan 2018 is a historic in the saga of swarm drone warfare, as that marks the date when the first recorded and organised swarm drone attack took place. It was reported that on this day a group of 13 GPS guided drones attacked the Russian air base at Khemmiem and Tartus naval facility in West Syria. Out of the thirteen drones that formed the strike package, ten attacked the air base while the other three attacked the naval base.³



<https://www.google.com/search?q=the+drones+that+attacked+the++Khemmiem+air+base+in+Western+Syria&tbm>

Russia being a strong air defence power claimed that seven of these drones were blown up with anti-aircraft missile systems while the other six were soft-killed by cyber warfare unit⁴. Out of latter, three of them exploded on landing, while three were retrieved intact⁵.

The inspection of the intact drones revealed that these were rudimentary in construction; the home-made, 'Do-it-Yourself' (DIY) variety. Powered by a single propeller, the drones had no landing wheels and were mostly made of wood and plastic.

The bigger questions in the Russian swarm attack

It is not of much relevance whether the Russians were able to beat the drone attack or otherwise, what is of relevance is the following:-

1. A new capability to wage aerial warfare which actually was simmering to unfold for some time, actually took shape on the night of 5/6 Jan 2018. The unmanned revolution just moved up another notch in lethality.
2. One should not be swayed by the fact that the machines were rudimentary and DIY variety etc. These were in fact 'advanced machines'. Sample the following⁶:-
 - a. Each machine had a control package and a fuel tank on board.
 - b. Each had a separate warhead which was composed of improvised explosives 'packed professionally' in the assigned coordinates.
 - c. The machines displayed excellent remote control capability of dropping the warhead precisely, on user command.
 - d. The GPS navigation capability of the explosives was technically very sound and of a high order. The Russians analysis showed that these were launched from a range in excess of 50 kms and guided (autopilot-flown) precisely to the targets.
 - e. The analysis also revealed that the drones probably had an attack range more than 100 Kms. This deduction was possible as the Russians were able to identify the launch site as Muwazarra in the Southern Idlib province of Syria; which is that far.
 - f. The programming and control of GPS guided vehicles to fly around 50 Km and drop the warhead precisely, is work of advanced engineering involving the use of satellite communication.
 - g. Probably the remote weapon delivery technique relied on precise instrumentation such as pressure transducers and altitude-controlled servo actuators.

It is no wonder therefore, that the Russians called the drones 'highly advanced machines.'

Anonymity??

3. While the Russians blamed the Syrian rebels who are active in the area of Idlib with full backing from Turkey for the attack while some other quarters saw the hand of US intelligence, the identity of the attackers essentially remained a mystery. Following are the implications of this fact:-

- a. If the Russian claim is to be accepted, it marked the ominous beginning of the dark era when a new but precise weapon of destruction reaches the hands of terrorists and other non-state actors.
 - b. It also proved the great advantage of anonymity that such attacks offer, wherein, a bunch of non-state actors can cause disproportionate damage and remain hidden. It is another point that in this case a lesser known terrorist group 'Free Alawite Movement' claimed the responsibility for attack.
4. The Russians launched their top of the line Pantsir S missiles (unit cost of the system - 13.15 - 14.67 million USD) to kill the seemingly crude drones proving the point that how a disproportionate cost can be slapped on the defender by such cheap machines as was the set of 13 drones.

Another Swarm attack

5 Jan 2018 was not destined to remain a 'never gain' event. On 14 Sep 2019 two Saudi oil production facilities in Abqaiq and Khurais operated by the state-run oil production company Aramco, were hit by a swarm drone strike disrupting and stalling some 5.7 million barrels of crude oil.



So devastating was the impact of the attack that it nearly halved the country's oil output.



<https://www.google.com/search?q=tswarm+attack+on+suadi+oil+facility+Sep+2019&tbm>

The assessment was again the same... swarming drones in the hands of non-state actors precisely navigated and controlled could cause disproportionate damage to their intended targets. This came to be corroborated as the Yemen based Houthi movement, which is waging a proxy war against the Saudi Government claimed the responsibility, stating that they had directed some 'ten weaponised robots' to the oil facility⁷.

According to a report published by the United Nations Security Council, Houthis are known to be using a drone called UAV-X which is also nicknamed 'suicide' or 'Kamikaze' drone owing to its feature of getting destroyed in attack⁸.

AI Powering Autonomous Warfare

In May 2018 an online architecture magazine named Dezeen premiered an 18 minute documentary titled Elevation. While this documentary essentially showed how the drones will change cities by revolutionising travel, deliveries, architecture and more by expanding human consciousness itself, it also warned that drones are potentially as 'disruptive' as the 'internet'⁹.



<https://www.google.com/search?q=elevation+by+dezeen&tbm=isch&ved=2ahUKEwig68ev1MH0AhVIB3IKHSw-BHYQ2>

Swarm drones that represent the above 'disruptive potential' as 'destructive potential' are becoming dangerously strong on the enabling wings of technology. Some experts have called it 'weaponising of AI'. Some salient points are enumerated:-

1. There are many advantages of using swarm drones as tools of warfare:-
 - a. It is a downright low-cost option to wage war as compared to the sky-rocketing costs of aircrafts, missiles guns etc.
 - b. Unlike any other weapons of war, save the high-cost intelligent ammunition (like loitering ammunition etc.), swarm drones have a tremendous edge in having a 'mind of their own'. Once programmed by the enabling tools of AI, these miniature warriors are capable of taking decisions, take default actions where no orders exist or where there is ambiguity and possess the capability to conduct 'intelligent autonomous warfare'.
 - c. Owing to their sheer numbers, they can simply overwhelm any capability of the de-

fenders in fielding kinetic countermeasures. After all, every sensor has a finite capability to track a certain number of targets and every air defence system has a finite target handling capability. What if that gets beaten by a count of hundred or even thousand! Conventional systems will just collapse, or may be, they will be able to take on a few out of the hundreds of miniature warriors.

Look at the Russian example. Out of just 13 drones, the mighty Pantsir-S could take out only seven. Suppose the attackers were 100 or say 500?

- d. Researchers are getting inspired by the 'motivation', 'inspiration' 'intellect' and 'resolve' (each word intended) of birds and insects to go about their task resolutely and decisively.

For instance, the lowly ant will ultimately succeed in climbing the wall even if it drops a hundred times, or will succeed in carrying a load many times its weight even if it takes a hundred attempts. The motivated termite will continue to build its colony without central control. The bees in the hive will go on doing their assigned job without the queen bee needing to command every bee every time.

The researchers are trying to replicate the above behaviour in swarm drones. The day is not far when the AI will actually empower the swarm to do the following:-¹⁰

- (i) Show a high degree of 'collective intelligence'.
- (ii) Exhibit a degree of 'resolve' and 'inspiration' to go about with the task assigned.
- (iii) Capability of each member of the swarm to act autonomously (but to a plan) without instructions from central control.
- (iv) Capability to quickly adapt and respond to unexpected changes.
- (v) Capability to disseminate information in huge groups and colonies almost instantly.
- (vi) Capability to operate on multiple frequencies to resist jamming yet, remain a part of one homogenous group.
- (vii) Capability of 'group think' to shoot down multiple threats simultaneously, quicker than a human brain can process. Something like 100 fielders with 100 balls with each fielder precisely shooting his own ball in the goal assigned to him/chosen by him!
- (viii) Capability to remember the path which they have taken to return back in default mode. It is said that ants use pheromones to remember the path they take from their nest to food. Based on this principle, a company in Switzerland (M/s Ecole) way back in 2018 developed an algorithm called SWAVNET (Swarming Micro Air Vehicle Network) that allows a body of swarming drones to mimic the above behaviour.

The above list is only limited by imagination. Not far in the horizon lurks the ultimate danger of the weaponisation of AI – ushering an era of autonomous systems that can

kill without any human intervention. That public pressure and ethical brigades will not let them release the genie out of the bottle; that is the hope today. The UN Secretary General, Antonio Guterres echoed these sentiments when he said that the prospect of machine with discretion and power to take human life is ‘morally repugnant’¹¹

Swarming Drones Getting Battle-Ready

Front runner countries around the world are realising the battlefield potential of swarming drones. Some random information is presented to drive home the point:-

1. As of Mar 2019, there was a report in the media quoting British Defence Secretary as saying that ‘swarm squadrons’ will be deployed by the British armed forces in the coming years¹².
2. Around the same time as above, it was reported that the US is working on a swarm drone programme dubbed as ‘Gremlins’ which involved micro drones designed to be dropped from planes to perform reconnaissance over vast areas. Also there are reports of front-line research in US having developed the capability of building drone intelligence to adapt and respond to unexpected threats.



Gremlin drone- USA

<https://www.google.com/search?q=US+gremlin+drone&tbm=isch&ved=2ahUKEwi2ip-Q3MHo-AhUKkEsFHfrUDhIQ2->

3. As late as in Feb 2020, there were reports of China having developed helicopter drones capable of carrying a variety of munitions like machine guns, grenade launchers and mortar shells which can move as a swarm finding their way to the designated target, carrying out engagement in an autonomous fashion and return to base without the human operator having to expose himself/herself to the front line¹³.



Chinese helicopter drones

<https://www.google.com/search?q=Chinese+helicopter+swarm+drones&tbm>

4. Earlier in Jan 2018, it was reported that China has tested a swarm of 1000 drones. For a full nine minutes, a body of 1180 drones sparkled in the sky in formation discipline marking the close of global Fortune Forum in Guangzhou on 07 Dec 2017¹⁴.

It is well understood that while controlling any number of display drones in any organised demonstration is essentially a coding and a software game, preparing hundreds of machines carrying variety of arms and munitions to take off for a far off destination and execute multiple tasks precisely and autonomously is a highly technical feat of weaponising AI. Something that can produce collective intelligence, hive behaviour, decision-making capability and more; China is close to this target.

5. US is reported to be working on the offensive uses of drone swarms for many years now. In 2018, a capability was successfully tested whereby swarms of could press ahead with their mission even if the communication with their human controllers was disrupted. This was referred to as Collaborative Behaviour in Denied Environments (CODE).

Also, on building offensive capabilities human managers are using the tools of virtual reality to control the formations of hundreds of drones. The acronym, given to this activity in US is 'Offensive Swarm- Enabled Tactics (OFFSET).



CODE and OFFSET Projects of US

<https://dronebelow.com/2019/03/27/darpa-updates-on-code-equipped-drone-swarm-project/>

<https://www.google.com/search?q=US+OFFSET+swarm+drones+project&tbm=isch&ved=2ahUK-EwjZrJXY5MH0AhWn4TgGH01PCMgQ2->

6. Swarm drone capability of Pakistan? Suffice to say that in times of need, China will not be found wanting. Also of relevance are two facts. One, Pakistan is currently at a stage when its home grown unmanned combat aerial vehicle called Burraq has matured for over four years now. Two, 48 high-end Wing Loong II UCAVs capable of teaming with the manned platforms is under sale to Pakistan¹⁵. When India was firming up on S-400, there were unconfirmed and uncorroborated reports of Pakistan trying to seek swarm drone support from China¹⁶.
7. In Nov last year there was much talk of the Russian Flock 93 concept. This concept, reportedly developed by the Zhukovsky Air Force Academy envisaged launching more than 100 drones each carrying a 5.5 pound warhead. This drone was to be a Vertical Take Off and Landing (VTOL) flying wing type of drone (probably Kalashnikov ZALA -KYB drone). Definite operationalisation of this capability has not been reported in the media but where is the doubt that such a capability (and more) is well within Putin's Russia's technological might¹⁷.
8. According to the reports just coming in, Russian attack drones (Okothnik and Altius) will

be operating with manned combat platforms like SU 57 in the MUM-T mode taking on the targets as designated by operating a totally autonomous mode. It can also detect best approach routes avoiding adversary's air defences thus saving manned platforms.



Russian Flock 93 and Okhotnik Projects

https://www.google.co.in/search?q=Russian+Flock+93+swarm+drones&tbm=isch&ved=2ahUKEwjX6_Xk58HoAhUMEnIKHbohCvkQ2-

<https://www.google.co.in/search?q=russian+Okothnik+swarm+drone&tbm=isch&ved=2ahUKEwjJvc636MH0AhU2k0sFHb8UDQoQ2->

Swarm Drone Capability of India

Where is India in swarm drone capability? The answer is 'up and about'. A lot of work is happening in India in swarm drone as well as related fields. Salient points are enumerated^{18,19,20,21}

1. The State-run Hindustan Aeronautics Limited (HAL) has joined up with a Bengaluru based start-up New Space Research and Technologies, a company which designs and develops 'Persistence Drones (implying long endurance drones) for the purpose of Earth observation and communications.
2. The above tie up is working on three Projects:-
 - a. Development of air launched swarm drone going by the name of ALFA-S (Air Launched Flexible Asset - Swarm).
 - b. Development of a robotic wingman unmanned drone.
 - c. Development of an ultra-high altitude drone.



<https://www.google.co.in/search?q=ALPHA-S+swarm+drone+HAL&tbm>

3. Following details of ALPHA-S are relevant:-
 - a. The system consists of small drones 1-2 meters long and capable of carrying 1.5 tonnes of explosives. The drones have foldable wings.
 - b. Due to their small size, some 30-40 of them could be carried on board a SU 30 MKI platform or on an upgraded Jaguar (Jaguar Max).
 - c. The drones have stealthy features. The on-board batteries which last a couple of hours can propel the drone upto 100 km/h.
 - d. When in flight, the drones are connected to the mother aircraft through infrared and electro-optical two-way data secured data link.
 - e. Once deployed by the manned aircraft, the drones scout for targets of opportunity. These could be any type of designated vulnerable areas, SAM sites and so on.
 - f. Once the target is acquired, it is destroyed by the drones in the Kamikaze mode of attack by achieving a catastrophic collision with the same.
4. As regards Robotic Wingman, it is an unmanned drone which is designed to accompany a manned platform in a Manned and Unmanned Teaming (MUM-T) mode also called the Combat Air Teaming System or CATS for short. Wingman will be about half the size of a fighter aircraft.



<https://www.ndtv.com/india-news/indian-air-forces-unmanned-indian-wingman-drone>

In the CATS mode three to four such drones could be flying about a 100 kms ahead of the manned systems providing the mother aircraft with battlefield situational data. The Wingman will have its own radar and sensor and will carry a Precision Guided Munition (PGM) which could be a laser guided bomb or an air-to-surface missile (future versions could also carry an air-to-air missile). A two-way secure data link like that of ALPHA-S will also empower the connect between the Wingman and mother aircraft.

5. The ultra-high altitude drone will have a capability of flying at some 65000 ft and will have an endurance of not less than three weeks. It was reported that at this altitude, it will be able to obtain real time information of areas deep inside Chinese territory even by keeping on own side of the border.

So that is the happening world of swarm drones where the encouraging fact is, that India is keeping pace with the front-runners.

On the flip side, swarm drones are a huge, huge threat far outside the capability of conventional kinetics air defence systems. How the defenders are gearing up to take on this challenge?

That is another world by itself which will require a full article space. May be the next one!

End notes

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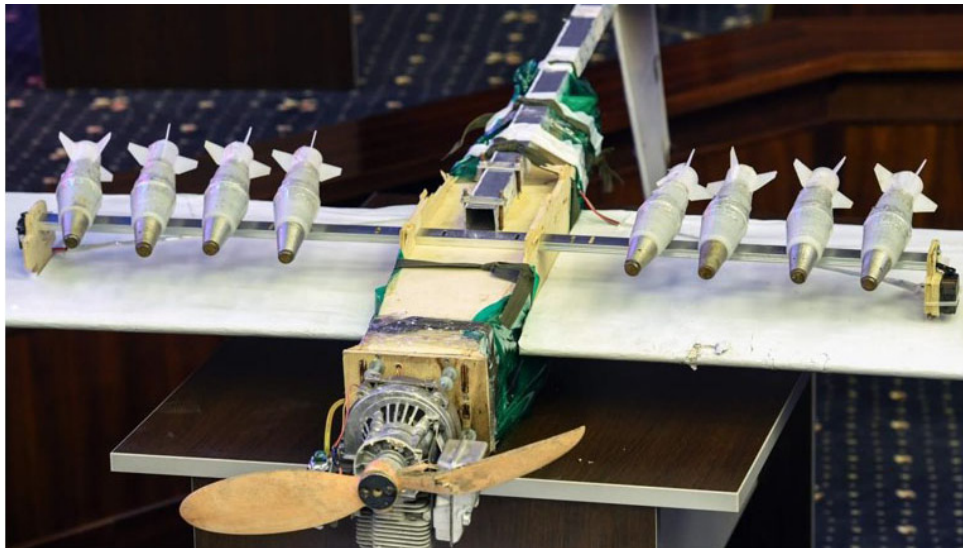
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Drone Swarms: Bracing up with The New Threat

A New Threat Knocks

On 05 Jan 2018, for the first time in recorded history, a set of 13 drones, appearing rudimentary in design and appearance, attacked the Russian Air Base at Khmeimim and their Tartus naval facility in West Syria¹.

A strong air defence power like Russia, even after committing its frontline Surface-to-Air Missile (SAM) Pantsir, worth millions of dollars, could kill only seven of the cheaply made drones that attacked the air base while the cyber unit, which tackled the other six, could soft kill only three. Three landed intact.



Drone swarms that attacked the Russian air Base on 05 Jan 2018

<https://www.google.co.in/search?hl=en&authuser=0&tbm=isch&sxsrf=ALeKk00HbML7z3jzbzTVHr8yYmfERVk8B5w%3A1586071215942&source>

On 14 Sep 2019, ten weaponised robots (one other report says 18 robots and 7 cruise missiles) attacked the Saudi oil facility at Abqaiq and Khurais. A whooping 5.7 million barrels of oil got stalled. The blow was so severe that it actually halved the oil output of the country....



One drone attack – 5.7 million barrels stalled

<https://www.google.co.in/search?q=swarm+drone+attack+on+saudi+oil+facility&tbm=isch&ved=2ahUKEwj7pnG4ND0AhUexTgGHYghD5AQ2->

Important to note that the drones in action in the above two incidents were a miniscule, just 13, 10 etc. What if this number is 100 or may be many times this figure? The cumulative catastrophic effect will be simply unimaginable!

Swarming drones are the latest arsenal in the tools of aerial warfare which are posing a grave and an unprecedented challenge to the defenders.

This article examines why this challenge is unprecedented and what is happening in the defenders' camp to brace with the new threat.

Why the Challenge is Unprecedented?

Building the perspective

It all started with single-propeller driven crafts carrying their valiant gunners who tried to train their machine guns on ground targets in a hit-n-trial mode. This was air threat at T0!

Times changed over decades, the aircrafts transformed into deadly fourth, fifth (and now sixth) generation machines armed-to-the-teeth, the attack helicopters surprised defenders by flying in the nap-of-the-earth and hit their targets suddenly at close ranges, the anti-radiation missiles or ARMs sounded a death-knell to all sensor-based equipment, the needle-sharp cruise missiles picked and destroyed their targets accurately, a whole generation of smart, intelligent and precision-guided munitions came up over time.... Times changed.

While the times changed over six-seven decades and more, it still remained under one class. The class was 'conventional air attack'.

To tackle this attack, over the same six-seven decades or more, came up a whole family of air defence weapons based on ground, sea and air and integrated as one whole.

‘The Conventional Attack-Defence Cycle’

Based on the above, the attacker-defender duel which was the norm till recently, had a typical signature. The same roughly unfolded like this:-

1. The attacker will put together an aerial threat package consisting of aircrafts, attack helicopters, ARMs, cruise missiles and more packed with state-of-the-art munitions and enabled by best of avionics technology providing such capabilities as long range, deep strike, precision, standoff kill capability, stealth muscle and more. The munitions included both the hard kill as well as soft kill.
2. The above threat package will be executed in very many different profiles, techniques and packages as to overwhelm the defences, one way or the other.
3. The defender on the other hand, will put up strong defences integrated over land, sea and air. Besides air defence aircrafts, such defences will comprise of air defence guns of various hues and a whole family of SAMs starting from a very short range and others going up to ranges of hundreds of kms. All these knitted together by a strong and an autonomous Battle Management Command and Control System.
4. The basic pattern would be to detect the air threat as far forward as possible, identify it to be friend or foe, prioritise the attack based on immediacy and lethality and bring to bear upon it seamless and successive fire, shifting from weapon to weapon as the threat drew inwards to its intended target.

The Game changers

The above battle sequence saw a paradigm change with the emergence of two very special weapons; Hypersonic and Drone Swarms.

Hypersonic

Hypersonic weapons are two types; Hypersonic Cruise missiles (HCM) and Hypersonic Glide Vehicles (HGVs). What is so different about them?

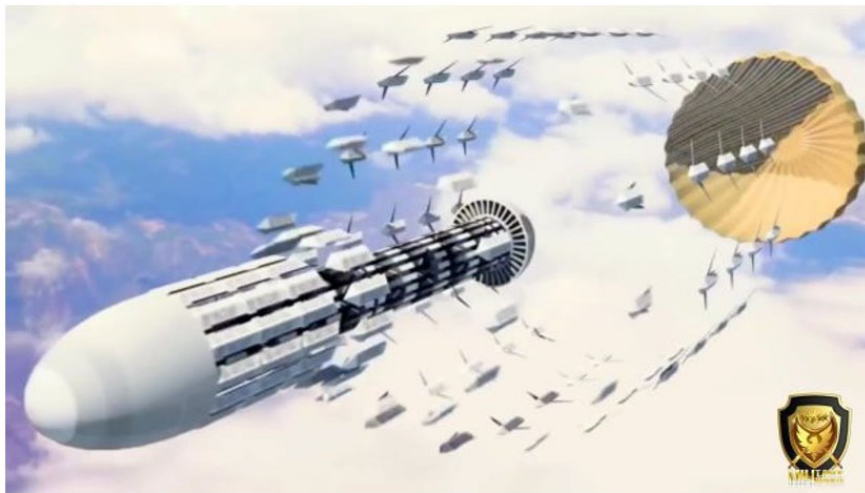
1. HCM and HGVs are capable of flying at speeds of Mach 5 (approx. 5000Km /h). To get a better grasp of what it means, this speed means that the vehicle is flying at 1.6 km/sec. Such a weapon has a capability to strike anywhere in the world in less than one hour!
2. As if the above was not enough, Mach 5 is no more the ‘going figure’. If the recent claims of President Putin have to be believed, the Russian Avanguard HGV is capable of flying at Mach 20-27 (24696-33,340 kmph) or the Chinese Starry Sky 2 HCM is capable of flying at 5.5 to 6.5 Mach².

3. At the above speeds, there is no way any conventional air defence or missile defence system in whatever state of readiness it may be in, can ever hope to even get such a target on its sensors, forget about tracking it or killing it by launching any air defence weapons, be it aircraft , missiles or guns.
4. Such weapons are therefore claimed to be un-stoppable and the conventional air defence battle chain as described above, is redundant and useless in countering this threat.

The Drone Swarms

The second type of weapons which are capable of making conventional air defence battle sequence redundant are the swarming drones. Why?

1. The biggest strength of the drone swarms lies in their sheer numbers. Much like the locust swarms which can eat thousands of square hectares of standing crop in a matter of minutes, while every single weapon in the armoury of the humans can only look helplessly, swarm drone present the same fait accompli.



Drone swarms-the future of aerial warfare

<https://www.google.co.in/search?q=swarm+drone+the+future+of+aerial+warfare&tbm>

2. The conventional air defence systems based on the trio of 'sensors', (radars, electro-optical systems etc) 'shooters' (aircrafts, guns, missiles etc.) and battle management systems are limited by 'finite capabilities'.

By that it is implied that every sensor has a peak limit of how many targets it can track at a time and every shooter has a limit on the maximum number of targets it can possible engage at one time. What if that limit is beaten by a count of hundred or thousand? Conventional systems will simply collapse.

An apt simile could be a few persons trying to stop a running stream of water by putting their hands in the flow of water as barriers. However hard they may try, the water will simply flow past all around their hands. Swarms can just do that. Conventional air defence weapon systems prove to be redundant and toothless against drone swarms.

3. Thanks to the enabling tools of Artificial Intelligence (AI), one other strength of drone swarms is their capability of 'group think' where each vehicle of the swarm perceives itself as a part of the total swarm grid. Consequently, any one or a couple of vehicles getting shot down has no effect on the swarm as the balance of vehicle re-adjusts to make up for the loss and the swarm continues to push ahead resolutely in completion of its assigned mission. Much like thousands of inspired warriors coming in like a wave-front and undeterred by the fact that a few of their comrades have fallen to their adversary!
4. Another capability of the swarm is their ability to take independent decisions (based on a pre-fed AI logic) where, either there are no orders or there is lack of clarity in the same. Swarms can avoid known air defence weapon concentrations and choose the best route to their target. These can move precisely through enclosed spaces, galleries, bottlenecks, doors, windows and pick and choose targets to be killed.



Intelligent drone swarms

<https://www.google.co.in/search?q=intelligent+swarm+drones&tbm>

5. Against such AI warriors conventional air defence weapons firing dumb or at best guided weapons have no chance. Drone swarms will be unstoppable by them.
6. If the defenders do the costly mistake of launching their SAMs in taking out swarms, the result will be a fiasco of killing a few hundred dollars with a few million. In any case, most of the swarm will go past while the SAMs will take out a few; that too at prohibitive costs!

Dealing with the Swarm Threat

The challenge can be broken down into two problem statements:-

1. How to detect the incoming drones?
2. How to kill them?

Detection of Drone Swarms

Following points are made:-

1. While, it has been stated earlier that each sensor, be it radar or an electro-optical device has a finite limit to 'track' the targets it has no limit for 'detection' of aerial targets, per se. The tracking implies that the device has 'locked on' to the target (the radar will continue to look at the target irrespective where it goes). Once the target is being tracked, the sensors get the capability of guiding air defence means (aircrafts, missiles, guns etc) towards the same. The detection on the other hand is simply painting on the radar screen airborne objects that are seen by the sensor device.
2. The point being made here is that radars suitably placed will be able to pick up an 'area target' like a swarm of drones.
3. The Saudi drone attack case is examined briefly in the context of the question; 'was detection of the incoming drones possible?
 - (a) At the Saudi Oil facility that was hit by the drone strike in Sep 2019 there were two types of air defence weapons deployed for its protection, namely, the US MIM-104 Patriot SAM system and Oerlikon GDF 35mm twin towed anti-aircraft guns with Skyguard radar³



MIM 104 Patriot SAM system



35mm gun with Skyguard Radar

Air Defence weapons deployed at Saudi Oil Facility

<https://www.google.co.in/search?q=mim+104+patriot+missile+system&ctbm>

<https://www.google.co.in/search?q=oerlikon+gdf+with+skyguard+radar&ctbm>

- (b) Expert analysis revealed that the 18 drones and 7 cruise missiles that were fired executed an ultra-low-level flight profile that enabled them to remain just below the radar horizon hence remaining undetected all the way⁴.
- (c) The problem therefore was not that the radars were incapable of detecting the incoming drones and cruise missiles but because the raiders adopted radar evasion tactics.
- (d) Suppose the radars were suitably deployed so as to cover ultra-low level region just over the horizon(may be, deployed on elevated platforms or on a gradually rising ground even if that was to be artificially created in the desert) these would have not let the attack vehicles go undetected.

(e) Skyguard radar though a 1970 design has seen many an upgrades over the years. Its version employed with GDF 35 mm, the radar operates in I/J/K band of frequencies (8-20 gigahertz or GHZ⁵). It has a range of 20 km and a resolution (capability to distinguish between two adjacent targets in range) is 160m⁶. It is felt that this sensor if deployed in adequate numbers and at correct places would not have let the raid go unnoticed.

4. The fortunate thing with drone swarms is that unlike hypersonic attack vehicles which simply give no time to detect, the swarms are relatively slow moving aerial vehicles which by virtue of their numbers present a target, large enough in its radar cross-section (RCS) as to be detected by a modern day sensor, be it a radar or an electro-optical device.
5. It is stated that a high-resolution radar preferably operating in 'fire control bands' (frequency bands where radar detects very precisely and can direct air defence weapons on the threat), and suitably deployed as to cover the threat envelope which may be low (30-300m) or ultra-low (<30 m), will in all probability, be able to detect incoming drone swarms. Such fire control bands are X (8-12 GHZ), Ku (12-18 GHZ), K (18-27 GHZ) and Ka (27-40 Ghz). A range of 18-25 kms and a range resolution of 150 m at 20 km are considered adequate.
6. In addition to the radars, the Electro-Optical (EO) sensor systems (operating in the band, 30-3x10¹¹Hz) complement the radar solution ideally. In that, if the radar is jammed or the radar cannot see the target for any reason whatsoever (target lies in the radar shadow/radar dead zone etc.-not explained further), the EO systems are likely to detect the target.
7. The ground based surveillance provided by the integral early warning and fire control sensors of air defence weapons deployed at the assets, could be backed with airborne surveillance (through Airborne Warning and Control System or AWACS).
8. In super-sensitive areas where the vulnerabilities being protected are national strategic and critical assets, the surveillance cover could be further reinforced with satellite-based surveillance in a 'fixed gaze' mode where the area over the asset is always in the surveillance pan of the satellite.

That much for the surveillance and detection of the swarming drones which is very much a possibility.

Killing a Drone Swarm?

Conventional Weapons- a misfit

To arrive at what will be suitable to kill a drone swarm, it is essential to rule out what is not. In that, the following air defence weapons will be unsuitable (read incapable) to take out a drone swarm:-

1. Surface-to-air-missiles (SAMs) of any range and variety from very short, to short, to medium to long range. Not only the same will be a case of trying to hit a fly with a sledge hammer, the SAMs will be able to take out just a few of the swarm members; the ones which lie their

warhead explosion zone (blast/fragmentation /heat /pyro etc). What about the balance of the swarm?

Besides everything else, such an option will be highly cost-skewed in favour of the attacker. A case of killing a few hundred dollars with many million dollars!

2. The aircrafts scrambled in the interception mode. Such a mode of attack will simply not be possible in a one-on-one aerial duel. Yes, if the swarm drone could be identified at a long range there may be a remote chance of using an aerial platform to carry out 'area bombing' with blast/fragmentation warhead provided collateral damage to own areas can be avoided.

Suitable weapons to counter drone swarms

Having mentioned the weapons 'not suitable', following are the type of weapons that are suitable:-

Conventional Mode

In the conventional mode, ground based air defence guns with rates of fire in the range of thousands of rounds-per-minute are capable of creating a ball of fire in a volume of space that is populated by a swarm drone. Keeping in mind that the density of the drones in a finite volume of space will be high there will be a good chance of debilitating large number of them. (For instance, M133 GAU- 17 Gatling gun has a rate of fire of 2000-6000 rounds per minute⁷)



M133 GAU- 17 Gatling gun

<https://www.google.co.in/search?q=M133+GAU-+17+Gatling+gun+&tbm>

Unconventional Mode.

In the unconventional mode, the ideal weapons to counter the drone swarms are the 'soft kill' weapons. Such weapons target the swarms along the following vulnerabilities:-

1. Attack the electronics on board the swarm vehicles in the following manner:-
 - a. Using killer laser waves to impinge on the miniature drones.

- b. Carrying out an electronic attack to jam/disable/disrupt the tele-communication and/or satellite-communication links of the swarm with the operators in the rear.

In various Defence Exhibitions/ Workshops and other such forums, anti swarm weapons have begun to make their appearance.

1. Such anti drone systems today are typically employing dual solutions both for the detection of drones, as well as, for killing them. Following is the pattern:-
 - a. A radar and an EO based dual sensor solution for detection of drones.
 - b. A laser and an RF based dual kill solution to achieve the kill.

A sample of some anti-drone solutions from various countries is presented:-

Israel

Israel, which faces the perennial threat of rockets and missile attacks (often fired in swarms) from the Hezbollah, has been testing several soft-kill weapons to take on the threat.

An Oct 2019 report from Israel stated that they have successfully tested a 5-10 KW laser weapon that could destroy drones upto 2.5 km⁹.

Israel later built the Drone Dome system. This system is a counter UAS (c-UAS) system employing the dual surveillance and dual kill system as described above. It has a range 3.5 km for a target with RCS of .002 m²⁹

China

China has showcased its anti-drone system called Silent Hunter. It is a 30KW laser system effective against low flying drones in the range bracket of 200m-4000m.¹⁰

USA

In Nov 2019, the US company Lockheed Martin showed its laser based anti- drone system called Advanced Test High Energy Asset (ATHENA)¹¹. This system employed advanced beam control technologies in directing a fibre laser on to the drone threat. c-UAS capabilities were claimed to a range of 4-5 kms¹².

Russia

Russia in 2017 came out with REX 1 anti-drone system whose upgrade appeared in 2020 as REX-2. As late as in Feb 2020, it was reported that the REX manufacturer M/s Zala Aero has come out with an anti-drone hand gun¹³.



Drone Dome System - Israel



Silent Hunter System China



ATHENA – Lockheed Martin



REX anti-drone hand gun Russia

<https://www.google.co.in/search?q=Drone+dome+system+israel&tbm>

http://english.chinamil.com.cn/view/2017-02/24/content_7501822.htm

<https://www.google.co.in/search?q=ATHENA+lockheed+martin&tbm>

<https://www.google.co.in/search?q=Rex+2+anti-drone+hand+gun+Russia &tbm>

All the Above Systems will FALL SHORT

While some anti-drone systems as briefly mentioned above are claiming success in defeating the drone threat, all of them (except maybe the drone hand gun if deployed in large numbers) are likely to fail or at best will prove sub-optimal in dealing with swarm drone threat. Why so?

All the above conventional laser systems are for killing a finite number of drones by tracking each one of them and directing killer laser beams on them. What if the drones present themselves in multiples of hundreds? How many the Drone Dome or Silent Hunter or ATHENA will kill? A very finite number which will prove to be miniscule when compared to the hundreds that are coming in for attack.

A swarm drone kill system will require some different capabilities. What could be these?

1. It must be an 'area defence' system.
2. The killing/debilitating effect it produces must not be restricted to a threat vehicle or two; it must engulf the whole airspace being used by the swarm.
3. The kill must be attempted on an umbilical cord controlling the entire swarm such as following:-

- a. The GPS/INS/4G/5G/LTE (long term evolution) link connecting the swarm with their operators.
 - b. Mass jamming of swarm network.
 - c. Mass frying up of swarm electronics and electro magnetics by an overwhelming laser/heat kill wave engulfing the entire threatened air space. (Very tall order!).
4. There is a need of going beyond laser and developing such area soft kill weapons that are based on 'charged particle beams' which come down as millions of charged 'lightning bolts' on the advancing swarms or the 'high power microwave' weapons that are capable of destroying the material integrity of the swarm body.
 5. It will be a hacker's challenge to try and take-over the swarm command through a hacking/phishing attack. A distant dream as of now.

These are the type of challenges which lie in the near future if swarm drone attacks are to be countered 'effectively' and 'economically'.

End Thought

It is felt, that like all other matters between the 'prosecutors' of the air threat and 'defenders' therefrom, the matter of killing the swarm drone effectively will also be settled in due course following the eternal cause-effect cycle and true to the dictum – 'To every sword a shield'.

Where is India?

1. Most of the details on the progress of laser based (and other) soft-kill weapons are in the classified domain. Suffice to say there is forward movement (privileged information not covered).
2. As late as Jan 2020, a capability to kill hostile drones using radio frequency attacks, as well as, laser kill beams was reportedly deployed to guard VVIPs in a parade in India¹⁴.

Drone killing? Fine. What about swarm killing???

It is like the Corona virus. The vaccine is under development!

End Notes

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