186-207

DRONES AS FORCE MULTIPLIERS

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Abstract

The drones are force multipliers whose presence in the combat has created an "unmanned revolution in military affairs". It will fundamentally reshape doctrine, military organisation, force structure, operations and tactics. Drones in various roles can act as force multipliers. The modern electronic warfare and air defense systems are challenging for drone operations in contested environments and hence they have to designed to operate in these environments. Also, the drones too have operational issues when the weather is bad and hence there is a need to look for solutions which can provide persistent coverage. HAPS is a drone which flies in stratosphere to provide persistent coverage. Current trends indicate that the loitering munitions and swarming drones that operate at lower altitudes can be challenging to detect, target and are not being sufficiently countered in our traditional approaches to control of the air. Drones can be used as an ideal vehicle for transport load in crisis conditions and hence there is a need to develop the ecosystem to make them ubiquitous.

INTRODUCTION

During the 1970s, the US, with its lead in microelectronics, was racing ahead in developing the reconnaissance-strike complex with a Revolution in Military Affairs to achieve the complete command of air and space using long-range precision weapons sensors to spot targets and networks. The "future wars," as it was hitherto believed, would no longer include major manoeuvres of massed formations, and the concept of conquering territories was no longer relevant. The age of non-kinetic Electronic Warfare, cyber and space warfare, and kinetic warfare with air strikes was speculated until Russia's dawn of special operations on February 24, 2022. Now, the application of armour, drones, and artillery competes with steel, explosives, and manpower in fighting WW-II trench warfare. The idea of correcting shellfire by aerial observation dates back to the American Civil War when observer balloons were extensively used. It was in 1911 that aircraft were employed as a means of power for the first time. Based on the experience of visionaries like Douhet, who witnessed the aircraft's performance in actual combat following the first aircraft deployment in war, the term "air power" was first used in 1925. The doctrine of air superiority as a prerequisite for the success of military operations has led to the growth of fifth generation fighters, characterised by incorporating stealth technologies.

The growth of unmanned systems and manned-unmanned teams is also turning the tables. The exploitation of technological developments to reduce costs while increasing the precision of weapon systems is where the growth of drone's role is proving decisive. The stability and reliability of drones in their flight, range, and duration have also improved and has become like aircraft, providing outstanding cost advantages and the ability to operate remotely. Now, they can perform the 4D functions, i.e., "Dangerous," "Dirty," "Dull," and "Deep" attacks into enemy territory without jeopardising pilot safety while securing air superiority. When integrated with various battlefield assets, drones will make an impact, especially when applied in the "management of time" strategy to our advantage and adversary's disadvantage.

New technologies are useless if not employed correctly. The 2020 Nagorno-Karabakh War highlighted how modern armed forces might engage in combat using various novel technologies, including loiter munition (LM), swarm drones, attack video drones, and other cutting-edge weaponry accessible to both state and non-state actors. The ongoing Russian-Ukraine special operation has become a test bed for emerging technologies and offers a glimpse of future technological challenges. The combination of mass and technology is the hallmark of modern conflict, and drones and satellites with a host of on board sensors [video and thermal cameras, signal intelligence (SIGINT) sensors, and edge processing incorporating AI/ML tools] have become the heart of precision and massfire. Russia and Ukraine started the conflict, both unaware of each other's surveillance and attack capabilities. The number of countries in possession of armed drones has crossed 30, and more than 100 countries have drones for reconnaissance.[1] It is relatively easy for non-state actors to acquire and misuse them.

Technology has changed throughout history and will continue to do so, and therefore, the Commander needs to strike a balance between a sound doctrine and new technologies to win battles. This article proposes to discuss the use of drones as force multipliers.

ELECTRONIC WARFARE

(EW) Electronic warfare refers to the conflict to control, affect, or disrupt the electromagnetic spectrum of the adversary. To do so, one may jam an adversary's communications, locate them by radio emissions, or interfere with their radars. The key to electronic warfare is being invisible to the enemy. The job of electronic warfare is to detect electronic signals from all kinds of weapons - including drones, air defence systems, jammers, artillery, and multiple rocket launchers. Countries with the technological edge in electronic warfare, closely linked to drone operations, will play an important role in actual combat. While aircraft are ideal for brute force jamming, drones are perfect for cases where a nuanced approach can be adopted by replicating similar behaviour & characteristics like manned aircraft, with a view to seducing the enemy to reveal its frequency of operations and later be jammed by fighter aircraft. While drones may be regarded as low-cost, low-risk, remotely controlled assets, they are vulnerable to the risk of snooping on communication radio signals, which could lead to the identification of base stations. The jamming interferes with the communication link of the drone, which is required to transfer data or the control signals to fly a drone remotely. This has led to the development of countermeasures against jamming.

The Russia-Ukraine war is an unsettling reminder of how the airwaves are thick with jamming as both sides seek to deflect drones and missiles. Artillery provides a substantial window of opportunity to manoeuvre forces like infantry and armour to assault defensive positions and seize them. They work out where the signals originate and the type of weapon, then pass on coordinates to other units that will aim to destroy the target. During the current Russo-Ukrainian conflict, gunners began firing Excalibur precision-guided shells early in the war. Though the ordinary artillery shells required many rounds to hit their targets, Excalibur, guided by the Global Positioning System (GPS), was accurate and needed one shot per target. But in March 2023, Excalibur shells began failing to destroy their targets because Russia started using powerful jammers that disrupted either the GPS signals, which guide shells to their targets or, (more likely), the radar fuse, which tells the shells when to explode. Similar reports have emerged from the airstrikes by Ukraine with US-supplied Switchblades, Joint Direct Attack Munitions-Extended Range (JDAM-ER) bombs, and High Mobility Artillery Rocket System (HIMARS).[2] The average life expectancy of a fixed-wing drone was approximately six flights: that of a simpler quadcopter, a paltry three.[3] A more recent study suggests that Ukraine is losing 10,000 drones per month.[4] Russia is significantly ahead of Ukraine in using drone jamming techniques.[5] In recent years, Russia has developed a range of jamming technologies[6] like:

- **Krasukha-4**, which targets airborne and air defense radars
- **Zhitel,** which suppresses satellite signals
- **Leyer-3**, a cellular and radio communications jammer.

A radio link used by a drone to receive commands from its operator can break down if there is too much radio noise, either through interference or deliberate jamming on the same frequency. When a drone's GPS signal is lost, causing it to stray, the drone wanders off due to the loss of connectivity. It can be forced to make a gentle landing attempt, return to the last place where it could receive directions, or just crash. To overcome the electronic warfare threats, the following solutions need to be adopted:

- Special receivers are installed to counter threats posed by the jammers. These receivers can receive encrypted signals from navigational satellites supported by National Positioning, Navigation, and Timing (PNT) signals and perform electronic shielding of the receivers. Also, the jammers are such powerful transmitters that they tend to interfere with friendly forces, affecting their operations. Hence, adversary jammers are often turned off to allow their own drones to function. This is the ideal opportunity to operate drones to target the adversary.
- When their GPS is jammed, drones can still use terrain matching, which involves comparing pictures of the ground below to a previously recorded map, just like cruise missiles do. It can be done with astounding precision, cheaply, and on a tiny chip, thanks to modern algorithms and processing power. The ground-launched small-diameter bombs fired by Ukraine have an Inertial Navigation System (INS) onboard, which is immune to jamming.[7]
- As GPS satellites being 20,000 kms away from Earth, transmit signals that can occasionally be "jammed" or drowned out by radio transmitters using the same frequency. As redundancy, signals from low-earth-orbit (LEO) communication satellites like StarLink, terrestrial transmission stations like Russia's Loran system, and magnetic-field navigation can be added to GPS. However, sending malicious code to drones during a flight can enable drones to evade these commands.
- Drones collect vast amounts of video footage, running into several petabytes per hour. They cannot send it all back because of insufficient

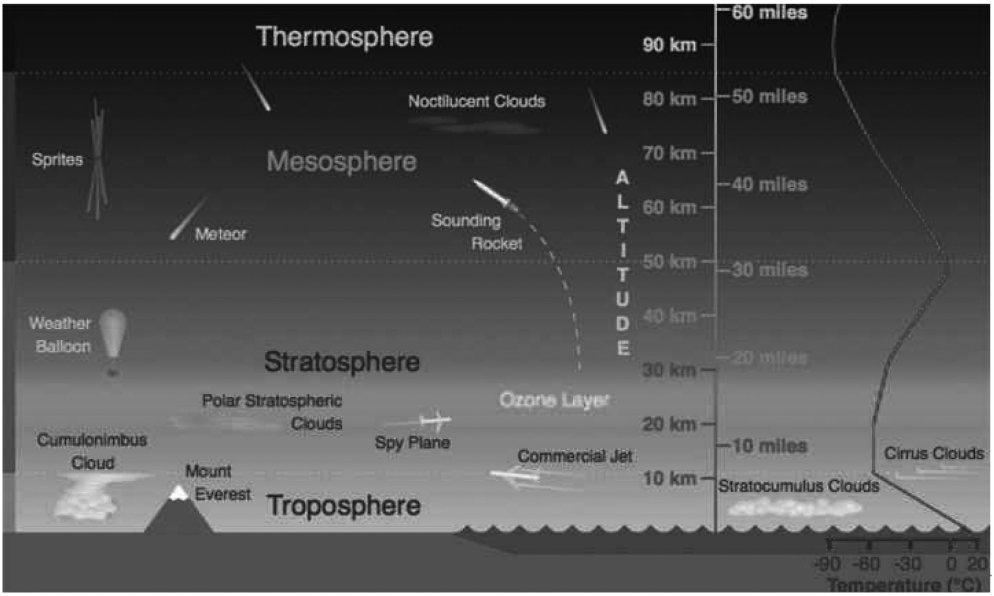
bandwidth and because communications are often jammed. The work must be done "on the edge," meaning within the drone. Many of Ukraine's drones have "fairly rudimentary AI capability" aboard. Small, low-powered chips can work out whether an object below is a T-72 or a T-90 tank, a job that could once have been done only on a distant cloud server. Even if its communications are intermittent, the drone may be able to transmit a few kilobytes of essential information—the target type and its coordinates.[8]

- Converted conventional aircraft have long been used as drones, primarily in the target role. The EW-capable aircraft are being converted into pilotless aircraft for electronic warfare (EW) and Suppression/Destruction of Enemy Air Defence (SEAD/DEAD). These missions are incredibly hazardous, often requiring flying directly at or near enemy air defences. Drones can achieve that without risking the life of a pilot.[9]
- Doppler frequency shift can sense relative motion. A low-flying drone can have a low-powered, lightweight self-defense system where the drone would broadcast ultrasonic tone outward from the drone. Tiny microphones fitted on the drone would listen to the reflections from incoming objects. The Doppler shift of these reflections would then be subject to onboard processing, permitting the drone to take evasive action.[10]

HIGH ALTITUDE PLATFORM SYSTEM

The LEO satellite constellation has been heralded as core to the resilience of both Ukraine's military forces and national critical infrastructure. These satellites have problems like limited communicable range, latency, and capacity to downlink large data. Therefore, many nations are developing High Altitude Platform Systems (HAPS) or High-Altitude Pseudo Satellite (HAPS). Hindustan Aeronautics Limited has already initiated the design work for indigenous HAPS and will be induced by 2024-25.[11]

Figure 1: The Area Above the Earth[12]



Source: Randy Russell, UCAR.

INTRODUCTION TO HAPS

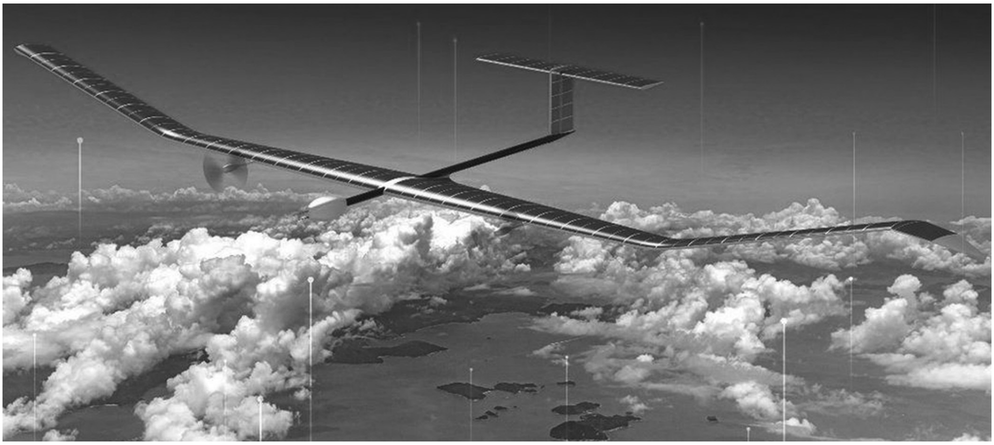
HAPS are Autonomous systems that include a fleet of craft (i.e., one or more uncrewed vehicles) and the systems that manage them. **The Near Space**, usually defined as the range of Earth altitudes from 20 km to the Kármán line[13] at 100 km from the surface of the Earth, has attracted worldwide attention for its great potential applications. The stratosphere is the most peaceful layer of the Earth's atmosphere, unaffected by the weather and is rarely wet. It has been shown from statistical data (Roney, 2007) that wind is the slowest between 20 km and 22 km yearly. HAPS can provide long endurance capable of staying aloft or loitering around a specified area, mostly flying between 20 km and 30 km. Artificial Intelligence (AI) and edge computing could play a role in the operations and management of on board HAPS systems. In addition, networking space assets and HAPS systems can act as airborne data centres with wide coverage and perform edge computing. Such information enables automated decision-making and can show trends, obscured patterns, and hidden relationships. Broadly, HAPS fall into two categories.

- **Lighter-Than-Air (LTA)** aircraft leverage buoyancy to maintain altitude. They may be equipped with some true airspeed capability, which may be turned on/off dynamically but is not necessary to maintain altitude or safe operations[14] with effective thermal management. They have precise station keeping and carry heavy payloads of up to 1000kg.[15]
- Fixed-wing **Heavier-Than Air (HTA).** These platforms require continuous propulsion and true airspeed to remain airborne in turbulent conditions. The payload of these platforms' capacity and flight duration impacts the aircraft's weight (less than 100kg).

HOW ARE THEY POWERED?

With the rapid development of renewable energy and high-powered material technology, several long-endurance near-space systems have been developed, including high-altitude airships, free-floating balloons, and drones.[16] Many major HAPS programme under development rely on solar energy to power them. The key advantage of this is persistence, enabling the platform to stay "on the station" for extended periods of time without refuelling. Solar-powered HAPS will be able to carry heavier payloads and be accessible in smaller forms as photovoltaic (PV) cell efficiencies rise. Airbus Zephyr has a wingspan of 25m and is powered by more effective PV cells[17] than NASA's (The National Aeronautical and Space Agency) Helios, which had a wingspan of 75m in 2003. The British-made 115 ft solar-powered drone, using a new weather and turbulence modelling systems aerial, can operate at a maximum altitude of 70,000 ft.[18]

Figure 2: Airbus Zephyr[19]



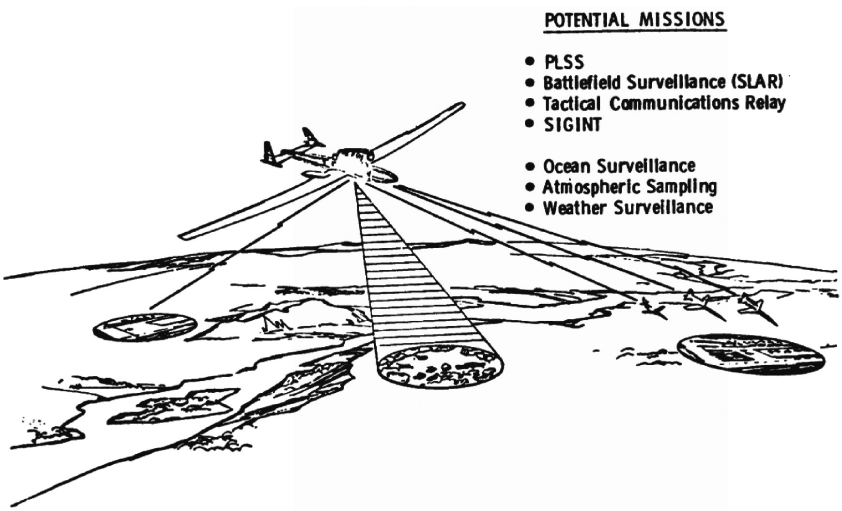
Source: Airbus.

Hydrogen fuel cells are also another option. The system weighs more overall than solar-powered options because of the fuel tanks and fuel itself. But hydrogen fuel cells can produce much more power than solar-powered substitutes, enabling the platform to carry a heavier payload. It also allows for 24/7 operations night and day without requiring to 'power-down' into reduced operations mode, as solar-powered Unmanned Aerial Vehicles (UAVs) need to do during the night and flights at extreme northern and southern latitudes.[20]

POWER ELECTRONICS

The role of power electronics responsible for converting and controlling electrical power is crucial for the operations of all on board systems. The reliability of these systems is where the HAPS is exposed to harsh conditions like radiation exposure, which causes significant wear and tear on power electronics, leading to potential failures. Efficient systems will enable the use of less energy for operations, thereby increasing the lifespan of HAPS.

Figure 3: Potential Missions of HAPS



Source: Wikipedia URL: https://en.wikipedia.org/wiki/High-altitude_platform_station

APPLICATIONS

Reconnaissance is undertaken to gather specific details, whereas surveillance is carried out to observe the area of interest persistently. To conduct tactical level warfare, the HAPS drones have distinct advantages of quality imaging, precision, persistence, ease of deployment, cost-effective alternatives, and security over satellites and aircraft. Satellites have a few advantages over drones regarding autonomy, accessibility, consistency, scalability, and cost. The airplanes will be best used in contested air space. Hence, it would be prudent to use the three resources synergistically. Though the debate on the vulnerability to missiles may remain,[21] three major applications are (a) telecommunications (b) earth observation and (c) GNSS (Global Navigation Satellite System).

- **Tele-Communications.** Wireless communications designers have researched including drones in their network architectures for three decades to provide cost-effective wireless connectivity for devices without infrastructure coverage. Low-altitude drones typically deploy more quickly, can be reconfigured more quickly, and have stronger communication channels due to short-range LOS connectivity than terrestrial communications or satellites. However, using highly mobile and energy-constrained drones for wireless communications introduces new challenges. The ability of HAPS to connect users in disconnected or poorly connected locations and give them access to the various services and applications offered by public and private ground networks is an additional important advantage of the technology. One of the domains that will benefit from a strong HAPS constellation network is cloud computing. This is particularly the case since the HAPS would allow the cloud to reach a wider range of users, enhance the Quality of Service (QoS) of traditional cloud applications, and establish new cloud services that benefit from the unique characteristics of the HAPS.[22] The HAPS are expected to be among the major networks that will assist the ground infrastructure in future telecommunication systems. HAPS are ideal for low-latency and mobile applications requiring continuous connectivity, as they relieve such applications from the burden of frequent handoffs in ground networks.

As next-generation communication systems emerge, new high-data-rate applications become prevalent. Consequently, network traffic has grown so fast that current backhaul networks will soon fail to handle all the traffic demands. A backhaul network provides connectivity between the cellular base stations (such as 4G and 5G) and the core network; it significantly impacts the performance of the whole network, and it is one of the major challenges beyond 5G and 6G. These backhaul networks could utilise one or more types of wireless signals (such as Radio Frequency (RF), Millimetre waves (mm waves), microwaves, lasers, and Free Space Optics (FSO) to provide self-sufficiency flexibility and encompass a wide range of application domains. Some advantages of aerial-based wireless backhaul networks are reduced cost, network scalability, ease of deployment in any area, and guaranteed Line-of-Sight (LoS) propagation.

- **Earth Observation.** Several factors are driving remote-sensor miniaturisation for HAPS applications. These remote-sensing instruments' smaller size and lower mass significantly impact power requirements, fuel consumption and mission life. Physics imposes some fundamental constraints on the performance limits achievable from the very smallest platforms. For example, high-resolution imaging requires large aperture optics, which may be difficult to accommodate on small platforms, even with deployable technologies. Similarly, microwave measurements may require huge antennas, especially at lower frequencies. Modern sensors can see things with unprecedented fidelity. Drones equipped with heat sensors are the latest weapons. Technology is pushing firepower and intelligence further down the chain of command. A tactical formation with access to mobile apps, loitering munitions, and LEO satellite communication terminals can see and strike targets. HAPS can be effectively used as an airborne platform for carrying out activities like Earth Observation (EO), multi-spectral, thermal (that seeks out targets by looking for heat signatures), LIDAR (Light Detection and Ranging) uses a pulsed laser to identify ranges of the Earth, Hyperspectral (for finer identification and discrimination of targets) and Radar payloads. The Synthetic Aperture Radar (SAR) sensor bounces microwaves off the Earth and measures the echo when they return; it can see through night and cloud cover but is much less sensitive to changes outside urban areas.

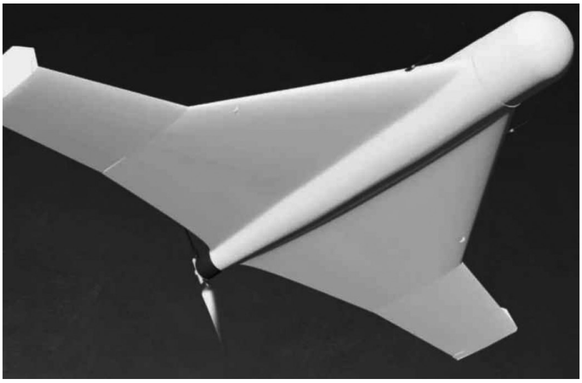
Finally, the conflict has proved that intelligence alone is not enough; it must also be used properly. Therefore, the software will track in real-time using satellite and drone imagery and visual recognition algorithms and target the adversary with unprecedented speed and precision. The software can deploy algorithms at the source so that only those images where the algorithms find valuable information are downloaded, saving time.

- **Position, Navigation & Timing (PNT).** The Global Navigation Satellite System (GNSS) is a network of satellites that broadcasts time and orbital data used for navigation and location calculations. GNSS applications fall into five categories: Location, Navigation, Tracking, Mapping, and Timing. The GNSS receiver on the ground picks up precise time signals from several satellites and calculates their locations by triangulation. The HAPS platforms provide functionality for navigation systems, additional ranging sources to assist and improve position, network nodes to provide data from an external source, reference stations for network RTK (Real-Time Kinematic) and PPP (Precise Point Positioning) types of services, and an additional sensor platform to perform radio occultation and GNSS reflectometry measurements.

KAMIKAZES MUNITIONS

For a long time, long-endurance drones like Reaper, Predator, and TB2 have been seen as reliable MALE (Medium Altitude Long Endurance) and HALE (High Altitude Long Endurance) drones known for intelligence, surveillance, and reconnaissance coverage, as well as capabilities for long-range precision strikes against critical targets. As Ukraine found out soon after its battlefront stabilised in October 2022, medium-sized armed drones are quickly shot out of the sky if deployed in heavily contested air space. This signalled the arrival of the smaller, cheaper, expendable, loitering munition drones as a force multiplier, which combines drones and missiles.

Figure 4: Potential Missions of Kamikazes[23]



Source: The Guardian.

Azerbaijan used the Harop to destroy Armenian air defence and armoured vehicles in a conventional mechanised conflict. These systems look attractive for many reasons: cost, reduced risks to pilots, and low training burdens. Warplanes are expensive to buy and maintain and may not be suitable for tactical battles; hence, the presence of drones makes a considerable difference for countries with small air forces and makes it an affordable air power. Kamikazes are recreational hand-held drones, ideal for tactical battle. They are different from UCAVs (Unmanned Combat Aerial Vehicles). UCAVs are combat UAVs that can fight against manned or unmanned platforms. There are four types of Kamikaze drones that have been popularised. They are:

- **Loitering Munitions** are the original, true kamikaze drones. The development of hand-held, tactical loitering munitions started in the early 2000s. The Ukrainians have used switchblades supplied by the US, with a longer loitering capability and infrared sensors. Russians have used Zala Kyb loitering munitions to attack fixed sites. Russian Lancets at about 15 kg are small enough to be caught by sturdy netting.[24] Based on air-to- ground technology, China is developing super-long-range loitering munitions with functions like communication relay, radar jamming, destruction and precision strike against time sensitive targets, and battle damage evaluation.[25]
- **Handheld Copter.** These are strictly not kamikaze drones, but rather recreational drones fitted with a device that allows the carriage and release of one or more grenades with reasonable accuracy. R18 is an octocopter, i.e. a vertical take-off and landing drone with eight propellers capable of carrying several kilograms of payload.[26]
- **First Person View (FPV)** drones also known as 'racing drones.' FPV drones are controlled by an operator wearing goggles (hence first-person view) and a Play Station-style console. FPV drones are fast becoming the most common due to their speed, agility and ability to loiter as well as fly. Ukraine is already fielding thousands of racing drones with improvised

warheads using First Person View (FPV) pilots and is built for speed and manoeuvrability.

- **Fixed-Wing Mini Drones.** Fixed-wing mini drones are strictly not kamikaze drones, as they intend to recover the drone after it has dropped its ordnance. The delta-winged Iranian-made Shahed 136 drone carries a small warhead of 50 kg and is more of a flying bomb, aimed at fixed sites like thermal power stations and power grids using a combination of mechanical guidance and commercial satellite navigation.[27]

In combined arms warfare, where the tanks and aircraft operate together, anti-tank munitions have been developed to neutralise tanks, and Surface-to-Air Missiles (SAM) have been designed to destroy aircraft. To seek and destroy the threats, the designers of loitering munitions reduced the risk of human harm. For neutralising armour, the sensors on board could be radar, thermal imaging, or visual sensor data and are optimised with a silent strike phase with high speed during the strike phase. Artificial intelligence, combined with the growth of sensors, allows greater autonomy. Once these drones are launched, they will fly around the missile installations for long durations, seek them whenever switched on, and destroy them. The targeting can be done selectively and can be aborted quickly. Russia is using the loitering munitions in pairs, with one flying above the other to serve as a backup if the lower one is downed. If the first munition is successful, the second can be directed toward a different target.[28]

DRONE SWARMS

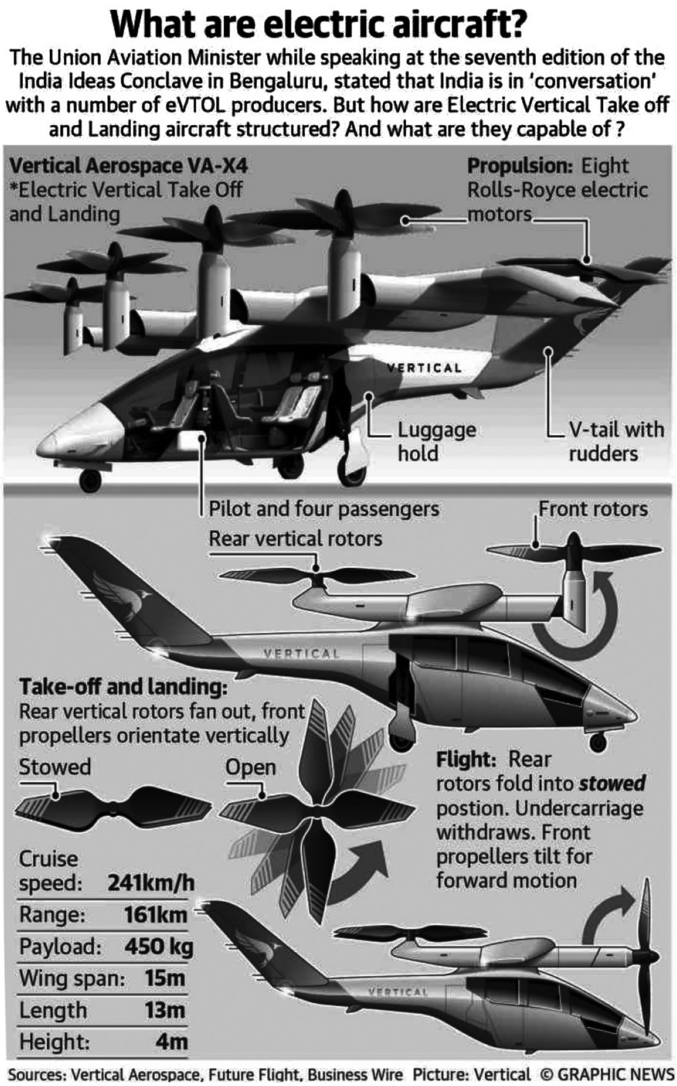
The advent of swarm drones allows each drone to operate independently to inflict damage without exposing the crew to risks. Military forces can use swarming drones in three ways: to attack, defend, and provide support functions such as intelligence, surveillance, and reconnaissance.[29] Unlike true swarms, which use artificial intelligence (AI) to operate autonomously, militaries are developing pre-programmed or remotely controlled swarms. The Artificial Intelligence (AI)-based autonomous weapons like swarming drones are tough to address because of the offensive–defensive dynamic they present. The only effective protection against attacking swarms may be defensive swarms. If this turns out to be true, then advanced militaries will be incentivised to develop swarms using Artificial Intelligence. Here is how the dynamic could play out: if defensive swarms are deployed, then the attackers may feel the need to create larger and more capable offensive swarms than the defensive swarms they will face. If offensive swarms are deployed, the defenders will need to deploy defensive swarms because that is the only way they will be able to defend themselves. It is easy to see how swarm development and deployment could lead to an arms race focussed on these technologies. The ultimate question that scholars, scientists, and policymakers are grappling with is whether lethal autonomous weapon systems should be banned, regulated, or allowed without restraint.

DRONES AS TRANSPORT

The current Ukraine-Russian conflict shows how war can hinge on logistics. All modern armies have two approaches to logistics: "pull" logistics, which involve responding flexibly to consumption and demand by field units; and "push" logistics, in which the supplies are dispatched based on pre-determined consumption rates. Military operations will increasingly depend on drones to deliver essential goods and services. The progress in materials science and the use of 3-D printers to produce critical components is an enabler. The military will also use drones used by law enforcement agencies, fire agencies and rescue personnel, postal services, telecommunications, agriculture, and emergency medical services to carry out various tasks.

- The Electric Vertical Take-off and Landing aircraft (E-VTOLS) have started flying overhead. To take advantage of drones' efficiency and speed, the introduction of autonomous drones in the market is just beginning. These are strikingly quieter than a helicopters, but if recharged from a renewable source of electricity, they are greener and, being mechanically simpler, a lot cheaper to run. The operating costs should fall even further, for E-VTOLs are readily adaptable to autonomous flight that frees up the pilot's seat for an extra passenger.

Figure 5: Vertical Aerospace, Future Flight Source



Source: Graphic News.

- Drones are equipped with high-speed motors can travel farther and faster than ever. At the same time, heavier payloads, long-distance transmitters, and batteries allow an operator to be far from the drone. The thermal-imaging cameras enable an operator to see clearly in the dark and commercially developed (or even improvised) object-release devices can deliver mortars and grenades while carrying out data theft. With the combination of these technologies, it is simple to imagine the inventive ways a drone might be used.

Source: IMR.

CONCLUSION

The ability to apply firepower economically with greater accuracy and precision with platforms in the air exploiting space and other assets exploiting the management of time to gain ascendency over the adversary is changing the nature of warfare. The potential use of unmanned systems is limited only by the nation's imagination. Modern warfare rests on three pillars— robust sensors to detect targets, increasingly precise munitions to hit them, and networks that connect the two roles of electronic warfare can affect all these three pillars. The Russian military has used the Iranian Shahed-131/-136 drones with its remaining missile arsenal to run the Ukrainian army out of air defense interceptors while significantly damaging Ukraine's electrical grid and critical infrastructure. Like introducing tanks or airplanes to the battlefield, one-way attack drones, loitering munitions, and quad copters are disruptive technologies that permanently change how wars are fought.

Due to the stable weather conditions and good electromagnetic properties, the development of HAPS is being undertaken to enable the deployment of systems for extended periods. HAPS can combine the persistence of a geostationary satellite with the low latency and manoeuvrability of a traditional fixed-wing aircraft and reduces the number of individual aircraft required to maintain continuous coverage. HAPS can provide significant benefits for communication support, atmospheric environment monitoring, disaster prevention, information collection, etc.

Drones are increasing being used for offensive roles in the battlefield. Autonomous vehicles have recently been generating significant attention on a global scale. AI and ML will play pivotal roles in ushering drones into autonomy. Though limitations like sensor errors and jamming to fool on board computers into crashing elsewhere persist, there is currently no effective counter to the adversary's loitering munitions and drone swarms. Induction of loitering munitions has led to armies dispersing themselves, hiding, and continuously changing their location to survive. Deception and camouflage are once again fashionable. Headquarters must shrink in size, relocate regularly, and mask their radio transmissions. Additionally, the Military operations will increasingly depend on drones to deliver essential goods and services.

Drones have relatively low costs and low barriers to entry, they improve a user's long-range precision-strike capability, and they can deliver multiple mission capabilities, including strike, reconnaissance, and battlefield communications, with negligible risk to human operators. However, they are vulnerable in contested environment. Even though leveraging new technologies to enhance leadership, mobility, communications, and intelligence capabilities is key to success, the commander should not depend completely on the modern technology to fight the wars. He must learn to strike a delicate balance between technological capabilities and doctrine to win the battle.

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NOTES

1. BBC News. 'A Combat Drones: We Are In A New Era Of Warfare-Here's Why"/, August 04, 2023, Accessed on April, 12 2023. https://www.bbc.com/news/world-60047328
2. Tiwari, Sakshi (2023). "Russia Now Has '100% Protection' Against US-Supplied HIMARS With Its Upgraded Defense System - Rostec." Latest Asian, Middle-East, Eur Asian, Indian News, July 14, 2023. Accessed on July, 20, 2023. https://www.eurasiantimes.com/edited-russia-has-100-protection-against-us-supplied-himars
3. "What Is the War in Ukraine Teaching Western Armies?" League of Ukrainian Canadians, December 3, 2022. Accessed on Jul31, 2023. https://www.lucorg.com/2022/12/what-is-the-war-in-ukraine-teaching-western-armies/
4. The Economist. July 03, 2023,"The war in Ukraine shows how technology is changing the battlefield", Accessed on July 31, 2023. https://www.economist.com/special-report/2023/07/03/the-war-in-ukraine-shows-how-technology-is-changing-the-battlefield
5. NewsweekJul25,2023,'Ukraine Admits It Lags Behind Russia In Anti-Drone Electronic Warfare' accessed on July 31, 2023. https://www.newsweek.com/Ukraine-Russia-War-Drone-Jamming-Shahed-Strikes-Unmanned-Vehicles-1815106
6. BBC News, August 04, 2023 "Ukraine's Invisible Battle to Jam Russian Weapons"Accessed on August 14, 2023. https://www.bbc.com/news/world-europe
7. The Economist, July 21,2023,"How Two New Munitions Could Affect The War In Ukraine", Accessed on July 31, 2023. https://www.economist.com/the-economist-explains/2023/07/21/how-two-new-munitions-could-affect-the-war-in-ukraine?utm_campaign=r.defence-newsletter&utm_medium=email.internal-

8. Ibid.
9. Charlie Gao, The National Interest, April 28,2021, "Pray That These 5 Drones Are Never Flying above You." The National Interest, Accessed on July, 2023. https://nationalinterest.org/blog/reboot/pray-these-5-drones-are-never-flying-above-you
10. The Economist, July 27, 2020"As Delivery Drones Multiply, They May Need To Protect Themselves"Accessed on August 12, 2023. https://www.economist.com/science-and-technology/2020/02/27/as-delivery-drones-multiply-they-may-need-to-protect-themselves
11. 'Aksheev Thakur' The Indian Express, July 13, 2023'HAL Allots Rs 42 Crore For First Prototype Of Pseudo Satellite; Accessed on July 31, 2022. https://indianexpress.com/article/cities/bangalore/bengaluru-hal-42-crore-prototype-pseudo-satellite-8024902/
12 Education, UCAR Center for Science. "Center for Science Education." Diagram of Atmosphere Layers | Center for Science Education. Accessed September 20, 2023. https://scied.ucar.edu/image/atmosphere-layers-diagram.
13. The Kármán line (or von Kármán line) is a proposed conventional boundary between Earth's atmosphere and outer space set by the international record-keeping body FAI (Fédération aéronautique internationale) at an altitude of 100 kilometres (54 nautical miles; 62 miles; 330,000 feet) above mean sea level. However, such definition of the edge of space is not universally adopted.
14. HAPS Alliance, Accessed on August 10, 2023. https://www.eurocontrol.int/sites/default/files/2023-01/2_ECHO%20Presentation%20on%20HAPS.pdf
15. HAPS-A Promise Not Reached https://kstatelibraries.pressbooks.pub/unmannedaircraftsystems/chapter/chapter-17-haps/
16. A Survey On Modelling, Control And Challenges Of Stratospheric Airships,February 2022, Accessed on August 20, 2023. https://www.sciencedirect.com/science/article/abs/pii/S0967066121002562
17. Pfeifer, Sylvia. "Airbus to Spin out Pioneering Solar-Powered Drone Programme." Financial Times, January 23, 2023. Accessed on August 15, 2023. https://www.ft.com/content/83aa4770-cfbc-4b77-8543-b797de2479f7.
18. Dean Murray, Zenger News, July 14, 2023 BAE Systems' Solar-Electric Drone Completes Stratospheric Flight Trial,Dean Murray, Accessed on July 21, 2023. URL: https://www.zenger.news/2023/07/14/bae-systems-solar-electric-drone-completes-stratospheric-flight-trial/
19. Airbus.com. Accessed September 20, 2023. https://www.airbus.com/sites/g/files/jlcbta136/files/2022-11/Zephyr.
20. Naval Technology, July 12, 2022: **High Altitude Platform Systems (HAPS): Technology Trends**, Accessed July 31, 2022. https://www.naval-technology.com/comment/haps-high-altitude-platform-systems-technology-trends
21. Cook, Ellie. "What Is Phasa-35? Cutting Edge Stratosphere Drone Passes Key Test in U.S." Newsweek, July 27, 2023. Accessed on August 23, 2023. https://www.newsweek.com/phasa35-high-altitude-long-endurance-drone-stratosphere-test-bae-systems-us-military-1815745
22. Ronkainen, Henrik, Jonas Edstam, Anders Ericsson, and Christer Östberg. "Integrated Access and Backhaul: A New Type of Wireless Backhaul in 5G." Frontiers, February 10, 2021. Accessed on August 23, 2023. https://www.frontiersin.org/articles/10.3389/frcmn.2021.636949/full

23. "May I Have a Word about … the Kalashnikov Kamikaze Drone | Jonathan Bouquet." The Guardian, March 3, 2019. https://www.theguardian.com/theobserver/commentisfree/2019/mar/03/may-i-have-a-word-about-kamkaze-kalashnikov-drone.
24 "Can Nets Protect against Kamikaze Drones in Ukraine?" The Economist. Accessed September 15, 2023. https://www.economist.com/the-economist-explains/2023/05/17/can-nets-protect-against-kamikaze-drones-in-ukraine.
25 Times, Global. "China's CH UAV Develops New-Type Loitering Munition with Super-Long-Range." Global Times. Accessed September 20, 2023. https://www.globaltimes.cn/page/202307/1294826.shtml.
26 Danylov, Oleg DanylovOleg. "R18 Octocopter from Aerorozvidka - Ukrainian Drone Destroying the Enemy • Mezha.Media." Mezha.Media, April 26, 2022. Accessed September 20, 2023. https://mezha.media/en/2022/04/26/r18-octocopter-from-aerorozvidka-ukrainian-drone-destroying-the-enemy/.
27. "Iranian Drones Pose a Fiendish Military Problem for Ukraine." The Economist. Accessed September 20, 2023. https://www.economist.com/europe/2022/10/19/iranian-drones-pose-a-fiendish-military-problem-for-ukraine.
28. Sullivan, Jack. "Iranian Shahed-136 Drones Increase Russian Strike Capacity and Lethality in Ukraine." FDD, March 21, 2023. Accessed September 20, 2023. https://www.fdd.org/analysis/2022/10/18/iranian-shahed-136-drones-ukraine/.
29. Lachov, Irwing. "Full Article: The Upside and Downside of Swarming Drones." Taylor & Francis Online. Accessed on August 19, 2023. https://www.tandfonline.com/doi/full/10.1080/00963402.2017.1290879.