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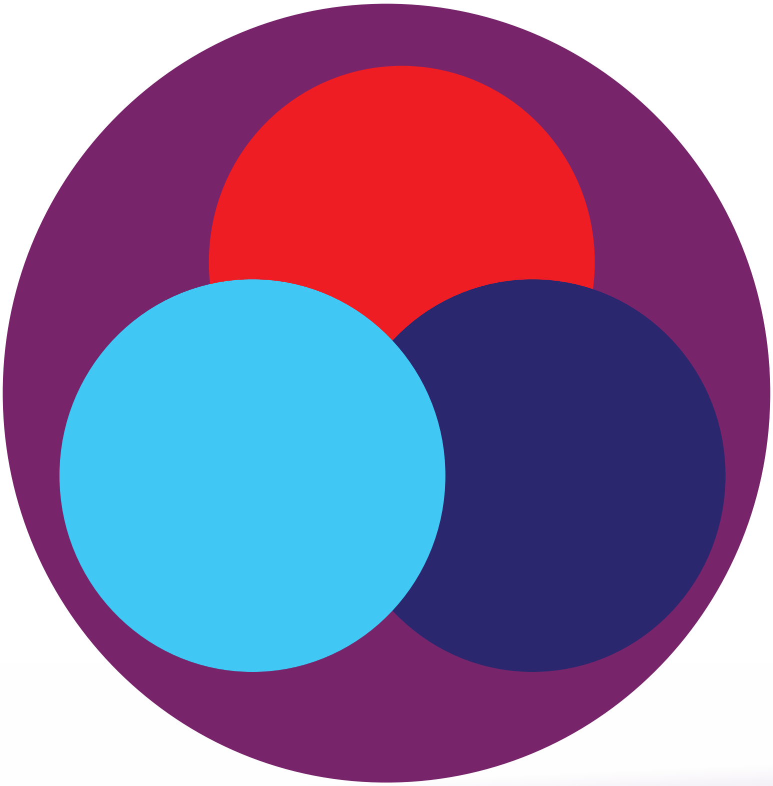
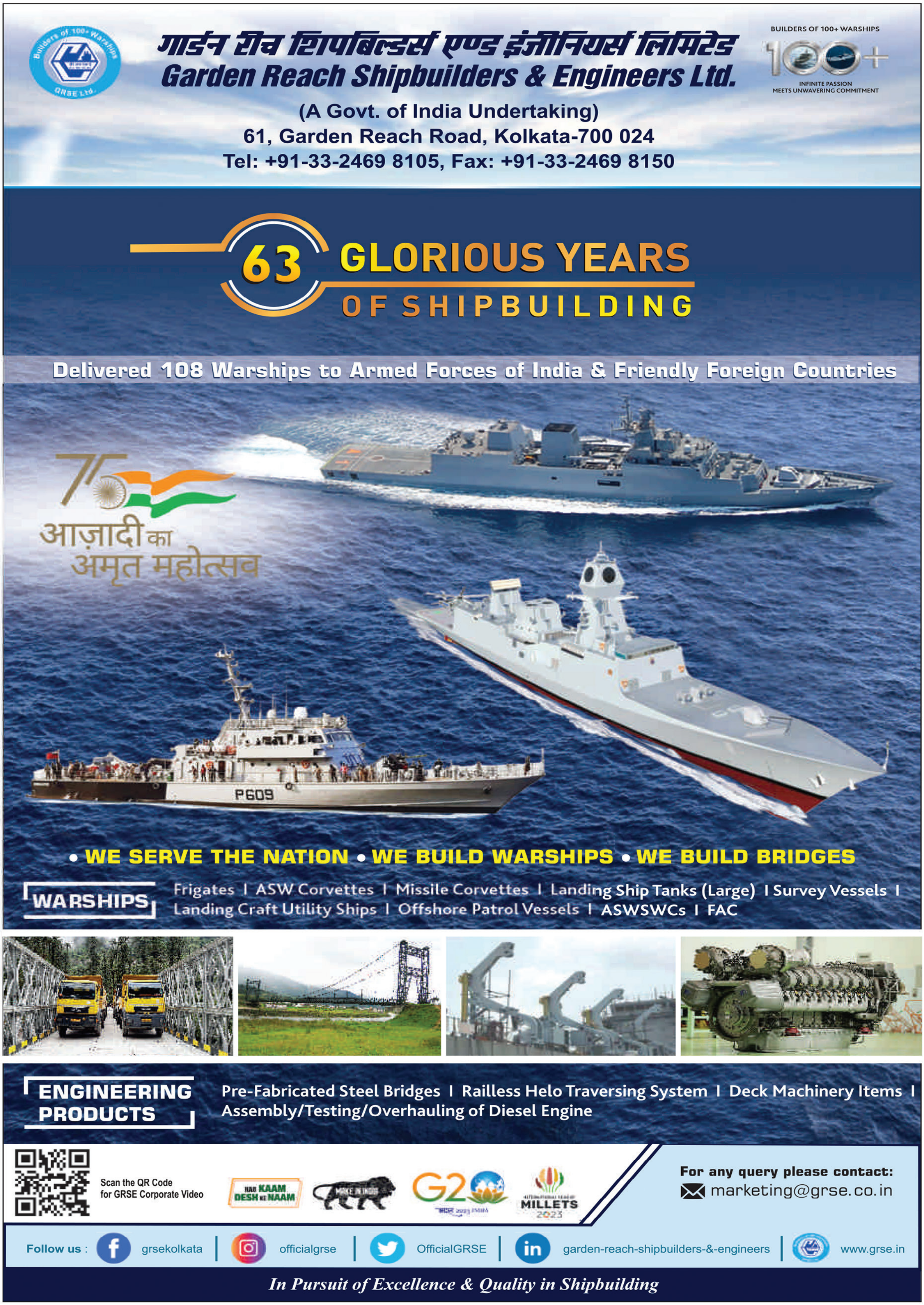


DRONES AND MULTI-DOMAIN WARFARE—PRAXIS AND PROGNOSIS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CENJOWS

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ABOUT US

CENJOWS was raised in 2007 as an independent think tank, registered under the Societies Registration Act, 1860. This aims to promote Jointness as a synergistic enabler for the growth of Comprehensive National Power and provide alternatives in all dimensions of its applications through focused research and debate.

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Notes:-

- Views expressed in articles are individual opinions of the writers, and not of CENJOWS.
- Contributors to Synergy Journal are requested to visit the website for the theme of the next issue and guidelines.

Lt Gen Johnson P Mathew
UYSM, AVSM, VSM
Chief of Integrated Defence Staff to the
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& Chairman CENJOWS

MESSAGE FROM CISC

Unmanned weapon systems are changing the character of warfare, manifest initially in the Vietnam, Lebanon and the first Gulf Wars as eyes in the sky, morphing as a hunter-killer weapon in the anti-terror wars of the 21st Century, and in the last decade, as asymmetric weapons of choice by non-state actors, and most recently in the Nagorno-Karabakh and Ukraine Wars, for generating attritable tactical combat power for outsized kinetic effects in conventional warfighting at scale, including deep strategic strikes.

Globally, the exponential growth of military drones is being spurred by ingenious repurposing of commercial drones and proliferation of dual use cheap technology. Beside the US, Israel and China, Türkiye and Iran are emerging as niche players in the military drone market. The near two year war in Ukraine has been a major test-bed, for both unmanned weapon systems and counter systems. 'Necessity is the mother of invention': we may have to closely watch the developments, especially in the Russian defence industry. The aerial domain has garnered the main focus, followed by the maritime and land domains. Industry 4.0 technologies are driving innovative research and experimentation for leveraging drones as loitering munitions, swarms and for manned-unmanned teaming (MUM-T).

The unmanned threats in the Indian context are both real and present, since both adversaries have leveraged the first-mover advantage, especially for weaponised exploitation. Besides, repurposed commercial drones are being leveraged by state-proxies, for drone attacks and dropping weapons and drugs. It is axiomatic that lessons from the ongoing Ukraine conflict will embolden our adversaries to leverage drones at scale in all domains as force multipliers for grey zone actions as well as hybrid warfare strategies.

The Indian Armed Forces have 25 years experience in exploitation of drones, primarily for intelligence, surveillance and reconnaissance (ISR). As part of the multi-domain joint capability development and transformation, accelerated procurement and indigenous development unmanned systems has gained focus, with policies incentivising active participation of Indian start-ups and industries. Even as indigenously developed tactical combat drones are nearing fruition, the extant inventory is being weaponised, and drone based ISR, strike, loitering, swarm, counter-drones and logistics capabilities are being enhanced in the surface, under-sea and aerial domains. Ongoing indigenous MUM-T projects will help ensure an overmatch in joint multi-domain warfighting.

Drones are not game changers by themselves and need joint integration with C2, fires, air defence, electronic warfare, communications and logistics, in all domains, creating a system-of-systems. There is a need to examine and debate evolving concepts, doctrines, practices and technologies. This comprehensive issue of 'Synergy' on Drones and Multi-Domain Warfare, therefore, is extremely timely and relevant. I am sanguine that creative viewpoints will generate constructive debates to help shape policies, doctrines, practices and joint capability development.

JAI HIND!

(Johnson P Mathew)
Lt Gen
CISC & Chairman CENJOWS

Lt Gen Sunil Srivastava
AVSM, VSM (Retd)**
Director CENJOWS

FROM THE DIRECTOR'S DESK

Much is being written about the ongoing Ukraine War, the first high intensity war where massed military and commercial drones are complementing air, land and maritime power by operationalising kill chains in innovative ways, despite high attrition in contested battle-spaces. With reduced costs and risks, the sustainable mass of the attritable military and repurposed commercial drones has augmented multi-domain combat capabilities manifold, accomplishing diverse functions including C2, intelligence, fires, surveillance, decoy, EW and sustenance. The asymmetrically high costs inflicted by drones, when integrated with combined arms with sophistication, on tanks, artillery, AD systems, naval, air and high value assets on the frontline and in depth, has accelerated the acquisition of drones at an unprecedented scale and pace, by militaries big and small. Testing and fielding of AI driven autonomous, multi domain loitering drones, manned-unmanned teaming and swarming, leveraging Industry 4.0 technologies has gathered momentum. Unmanned systems have triggered heated debates on their impact on warfighting in the air, air littoral and the sea (surface and sub-surface), much as the tanks in the Second World War.

This transformative change is shining a spot light on the need to debate the multi-domain combat potential of drones with rigour, to arrive at concepts, doctrines and tactical procedures for exploitation of drones and anti-drone systems, by all stakeholders- the joint armed forces, policymakers, R&D fraternity and the industry.

The concept note of CENJOWS, calling for research papers hitherto unexamined facets of multi-domain warfighting with drones, received an overwhelming response. Selected papers which examine various sub-themes in depth have been compiled in this edition of SYNERGY.

The first three papers explore the evolving concepts of warfighting in the air and surface domains, air littoral and combined arms warfare. Unmanned systems of the PLA in the Western Theatre Command have been analysed in great detail next. The next two papers analyse various dimensions of manned-unmanned teaming in the maintains and in a contested environment. The challenges of fusing intelligence/IMINT from manned assets, drones and satellites have been explored in the next two papers. Another paper delves into the integration of drones with long range precision fires and time sensitive targeting. With use cases for drones limited only by the imagination of the users, the next three papers explore the force multiplier impact of drones, especially in the aerial and maritime domains. Another paper suggests a novel framework for integrating drones in border management. The last two papers explore pathways for enhancing the civil-military fusion, R&D and innovation in the drones ecosystem for the Indian Armed Forces. Joint counter-drone capabilities and the need for joint resilient networks have been discussed in most papers.

Several incisive research papers, which we could not include in this compilation due to constraints of space, will be published on our website. We are sanguine that these thought provoking papers will ignite constructive debates on extant doctrines

(Sunil Srivastava)
Lt Gen (Retd)
Director

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DRONES: CHALLENGING AIR AND LAND WARFIGHTING PRECEPTS

Lt Gen Sunil Srivastava, AVSM, VSM** (Retd)

Abstract

Recent conflicts have generated heated debates on prosecution of conventional wars. Unprecedented exploitation of drones at scale, despite their vulnerabilities in a contested environment, potentially segmenting the air domain in the air littoral and blue skies, is challenging long held precepts on air superiority, air denial, control of the air littoral and massed use of drones. This article analyses the implications of the evolving paradigms for the aerial and surface domains, in context of the trajectory of the unmanned capabilities, and draws relevant lessons for the Indian Armed Forces, suggesting measures for leveraging drones for air superiority, air denial, responsive control frameworks for control of the air littoral and close air support.

GROWING DEBATES ON TRADITIONAL PRECEPTS

Future Conflicts-Contested Control of Air. The contrast between the ongoing Ukraine war, and the Gulf War-1 (1991), the last *major land and air war*, could not be more striking, despite the asymmetrical technological and numerical superiority of the attacking major power in both wars. The ineffective *destruction and suppression of enemy air defence (DEAD/ SEAD) operations by the Russian Air and Space Force (VKS),* despite engaging 75% of Ukraine's known air defence (AD) sites during the first 48 hours, could not cripple the forewarned and agile, though smaller, *Ukraine's Air Force (UkAF) and AD*. Eighteen months into the war, despite a 6:1 advantage,[1] *the VKS lacks air superiority, and is constrained to operate from friendly territory, exploiting its standoff advantage to support*[2] *its land forces. The UkAF, denied control of air on the battlefront, cannot support*[3] *Ukraine's floundering counter-offensive.*[4] *With both sides seeking mutual air denial and contesting local air superiority at the battlefront,*[5] *the attritional slugfest is getting prolonged.*[6] *Besides* the underwhelming performance of the vaunted VKS,[7] *agile air denial by Ukraine has kept the VKS at bay.*[8] While it will be naive to sketch the contours of the future air wars in the Indian context in absence of granular details of the conduct of war, *it will be fair to assume that, given the air power balance between the adversaries, control of air will be heavily contested, and windows of air superiority will be fleeting, at best*. Analysts argue that the time needed to achieve meaningful SEAD may be unacceptably long, jeopardising joint surface operations, and the only alternatives are to either have stealthy penetrating offensive counter air (OCA) capabilities, including large amounts of stand-off, stand-in and loitering munitions, or make the surface forces stronger, less reliant on air support.[9] *Implications of such assumptions for air and surface operations need to be examined*.

Drones and the Air Littoral-Is Ukraine a Precursor? *Unmanned platforms (drones), hitherto typically exploited asymmetrically by one side*, are being *used at scale by both sides in a major conventional conflict, ushering a drone war as a first, both close and deep. Attritable military and re-purposed commercial, including First Person View (FPV) racing drones,* are *being used at scale,*[10] *crippling traditional platforms* like tanks, guns, ships and parked aircraft. It is reported that Ukraine's crowd sourced '*Army of Drones*' now has 200 drone manufacturers, *including famed Antonov*, with 30 new indigenous models recently ordered.[11] The *impact of drone warfare is significant in the air littoral (*airspace contiguous to the surface, but below the operations of combat aircraft*), a new mini-domain,*[12] *which is critical for surface operations.* Russia, too, aims to manufacture 6000 drones by 2025.[13] The *'replicator' program* of US envisages several thousands of small and cheap unmanned systems (land, air, sea, below the sea) by 2025, leveraging attritable autonomy and *creating mass to fight China's might*.[14] The US Navy wants thousands of drones under the Super Swarm project.[15] Experts opine that in the next *10 to 15 years, about one-third of the world's most advanced militaries could be robotic*.[16] Employing UAS for a wider set of missions is one of the five priorities recommended for the USAF.[17] *In the Indian context*, the *northern adversary is a military and commercial drone leader*, with a few systems combat proven across the globe. India's *western adversary has an inventory of proven Chinese, Turkish and indigenous drones, having exploited them in combat since 2015*. It uses repurposed commercial drones for border violations. *While India presently has an inventory of unarmed MALE drones and few Harop anti-radiation munitions (ARM)*, induction of small/tactical drones (surveillance/kinetic) and loitering munitions (LM) has commenced at a frenetic pace. It will be *reasonable to surmise that any future war in the Indian context will witness exploitation of drones in the air littoral at a scale comparable to the Ukraine conflict*. *Operational and technological implications of exploitation of drones for the surface and aerial domains, specifically the air littoral, need an incisive examination*.

FUNDAMENTAL DOCTRINAL PRECEPTS

- **Air Supremacy/Superiority**. As per the Indian Air Force (IAF) doctrine, the degree of control of air varies from *Air Supremacy* (nil enemy air interference), *Air Superiority* (minimal enemy air interference) to Favourable Air Situation (FAS- limited in time and space, with greater enemy air interference).[18] The *western doctrinal equivalents are air supremacy, superiority and parity, respectively*. While mentioning command/control of air, the Chinese doctrines stipulate no such gradation, but some analysts argue that instead of seeking prolonged control of air over all areas, PLA might pursue air superiority *for key tasks at key times and over key areas*,[19] *especially prioritising counter air and missile defence and EW capabilities*.[20] *IAF doctrine accords* priority to *control of the air* through *Offensive Counter Air (OCA) and AD Operations*.[21] The networked, layered and agile AD capabilities of India's adversaries, buttressed by drones, electronic warfare (EW) and cyberattacks, will likely present a challenge, *and* proponents hold varying views on control of air.[22] *With each side securing FAS at best, we need to debate its implications for air and surface operations.*

• **Air Denial**. *Air Denial* does not figure in air force doctrines. However, its equivalent in maritime warfare, *Sea Denial (disputing command of the sea),* conceptualised by Sir Julian Corbett,[23] is one of the missions for the Indian Navy.[24] Successful air denial has kept the VKF outside the Ukraine controlled airspace,[25] by remaining a *force in being,* like sea denial *with a fleet in being.*[26] *Counter arguments hold that only weaker states may prefer air denial strategy*[27] *to fend off a stronger air force, till favourable air control is gained.*[28] Cheaper, distributed mass and agility help survive attrition to keep the airspace continuously contested. The *Anti-Access Area Denial (A2AD)* capabilities of near-peer adversaries *make the quest for air superiority costly, and air denial a pragmatic option, especially where the overall strategic intent is to deter and defend. Mutual air denial, right to the edge of the battlefront, helps hold deterrence.*[29] *Air superiority and air denial are not binary options, and could be pursued sequentially or in parallel, along different fronts, based on situational priorities.*

• **Control of the Air Littoral**. *Though Ukraine initially led the exploitation of the air littoral*, the Russia followed suit,[30] restoring parity. *Given the affordability and proliferation of drones in the air littoral, the salience of controlling this space will grow exponentially for the ground forces. Command and control (C2) and integration of air littoral assets, counter-UAS (C-UAS) capabilities and* Air-Space Management (ASM) *need a holistic examination*.

• **Tactical Surface Operations and Drones**. The IAF doctrine holds that *once some degree of control of air is achieved, subsequent air and surface operations can be coordinated* to maximise application of combat power.[31] Conducted in parallel with Strategic Air Operations, Counter Surface Force Operations (CSFO), *are coordinated air operations carried out for* surface forces *either to further their objectives or an integrated military objective*, to deter, *contain or defeat the enemy's surface forces.*[32] Under situations of fleeting FAS or air denial, *CSFO, which includes Battlefield Air Strikes (BAS),*[33] *the doctrinal equivalent of western Close Air Support (CAS), may be constrained, as in the Ukraine conflict, where drones and artillery have supplanted this mission. This calls for an examination of measures to enhance the efficacy of BAS by manned aircraft, armed/attack helicopters with drones and organic surface forces fire power (rockets, missiles, artillery).*

- **Drones, Deniability and Escalatory Dynamics**. *Drones provoke with deniability*, complicating response options, thus, potentially engendering *miscalculations*. *Escalation dynamics* are more complicated *where the sovereignty over disputed borders is contested*. In 2001, China released the *manned EP-3* only after a *formal apology from US, but* in 2013, it used a drone to violate the Japanese sovereignty over Senkaku.[34] Clearly, with lower political costs, drones are ideally suited for challenging *sovereignty.*[35] The US chose not to retaliate when Iran shot a MQ-4C in 2019. In grey situations, therefore, drones would be preferred to push the boundaries.

COMBAT MASS- DRONES ENABLING AIR SUPERIORITY

The Debates. Traditional *belief holds that some planes will always get through,*[36] since defence, spread thin, invites defeat.[37] In practice, Ukraine has denied air superiority to VKS,[38] *localising it in time and space,*[39] leading analysts to advocate *air denial over air superiority.*[40] Analysts have countered the view that airpower is inherently offensive,[41] averring that *defence scores over offence, since ground based AD (GBAD) can exploit mobility, density and expendability to deny air superiority* with a *volumetric and layered defence (lateral & vertical),*[42] *advocating a more balanced mix of high (crewed) and low (un-crewed) capabilities.*[43] The argument holds that *OCA operations* are costlier than *Defensive Counter-Air (DCA) operations which create a threat in being,* with open skies and technology *favouring cost effective air denial,*[44] *e.g. despite NATO's air superiority in Kosovo (1991), Yugoslavia's agile AD remained a credible threat*.

LEVERAGING DRONES TO CONTEST THE CONTROL OF AIR

That *control of the blue skies (operational air) does not extend to the air littoral (tactical air), was demonstrated by ISIS against the* US in Mosul,[45] operating repurposed commercial drones *below 2000 feet.*[46] Azerbaijan executed effective SEAD by exploiting relatively cheaper unmanned assets in its conflict with Armenia in 2020.[47] The increasing cost of multi-role manned aircraft *demands better options to generate the mass needed to gain control of air in contested environments. There is a need to leverage autonomous/loyal wingmen (LW), swarms and cheap LM, which* could also become aerial mines.[48] Dispersed warfighting in Ukraine has led analysts to argue for air denial with drones and mobile short range air defence (SHORAD) and man portable AD (MANPAD) in asymmetric situations like Taiwan,[49] *exploiting the enemy's lack of air-land integration.*[50] Low signature cheap drones *have the virtue of mass without the vulnerabilities of concentration,* with interoperable C2 networks.[51] However, drones which can make a winning difference will need better survivability, autonomy, sensors and payloads,[52] than the ones used in Ukraine. The USAF has *argued that cheap unmanned aircraft could potentially help mitigate aircraft inventory shortfall*s.[53] *The IAF doctrine holds that drones, unmanned combat aerial vehicles (UCAV) and counter-UAS have made the battle-spaces a dense environment* and their usage needs nuanced assessment, considering their capabilities, benefits and vulnerabilities in a contested battle-space.[54]

- **AI driven Autonomy in Air Combat**. Human judgment, though superior, is slower than machines, and *is a limiting factor* when the battle rhythm goes high, as in air combat. Underscoring the salience of AI, Chinese military scholars anticipate *battlefield singularity*, when combat gets faster than human cognition, ushering hyper-war, with unintended escalations spiralling out of control.[55] In DARPA's Alpha Dog Fight, AI pilots are repeatedly beating human pilots in manoeuvres and targeting.[56] However, all human functions cannot be automated.
- **Autonomy and Drones**. Autonomy in kill chains has three different *dimensions*- the *human control* (in the loop, on the loop and out of the

loop); *complexity* (automated, autonomous and intelligent); and *the function automated* (tracking, identifying, selecting, prioritising, timing, striking).[57] Guided munitions, even with *in-flight re-targeting*, are not autonomous, since humans select the targets. Even LM, *which selects and hits targets*, is limited in time (endurance), space (footprint); is designed for a specific target type and the target area is human controlled.[58] *Drone swarms can be potentially truly autonomous*.

- **AI Driven MUM-T - Generating Mass to Gain Air Control**. AI driven Man-Unmanned Teaming (MUM-T) enhances situational awareness, lethality and survivability. *The supporting role of a LW has been transformed with* AI and data-links, *operating beyond visual range (BVR)*, collaboratively penetrating the enemy's A2AD bubble with *mass and precision, absorbing attrition*.
- **Global Trends in MUM-T**. The US *third offset strategy is leveraging narrow AI driven MUM-T,* bolstering the capabilities of human warfighters,[59] fusing human creativity with technological precision,[60] under the System of Systems (SoS) approach of Next Generation Air Dominance (NGAD) program. The US plans at least 1000 highly autonomous, swarm capable and mission tailored *Collaborative Combat Aircraft (CCA), with the first batch entering service in the late 2020s, teaming two CCAs each with 200 NGAD platforms and 300 F-35s.*[61] CCA project will leverage the ongoing MUM-T projects like Air Combat Evolution (ACE) for collaborative AI powered dog fighting and the Skyborg project, which tested UCAV prototypes MQ-20 Avenger, XQ-58 Valkyrie and MQ-28A Ghost Bat (Australia). The US has successfully AI piloted X-62A, a modified F-16, in within-visual-range (WVR) and BVR fights with a simulated opponent.[62] The US proposes to equip six F-16 fighter jets with AI-enabled self-flying capability, to refine CCA autonomy.[63] *The NGAD SoS*[64] *approach facilitates* spiral development.[65] The US Navy jets have demonstrated refuelling and ISR with unmanned MQ-25, besides collaborative MUM-T between ships and unmanned surface vehicles (USVs). The UK, drawing lessons from her closed LW Mosquitoes and swarming Alvina drone projects,[66] has launched the

Lightweight *Affordable Novel Combat Aircraft (LANCA) - Follow on project*, and envisages a future fleet having 80% un-crewed assets.[67] *The VKS, which has been experimenting with an unmanned S-70 Stealth UCAV Hunter* as a LW paired with Su-57 since 2019, *reportedly used the prototype in Ukraine in a standalone mode.*[68] The second pilot of the Chinese J-20[69] would operate LW AVIC-601-S[70] and FH-97A,[71] the latter with radius of action of 1000 km. A US Army study had established that *the maximum number of UAS that could be controlled was two as managing three created extremely high workload for the pilot.*[72]

• **The Indian MUM-T Trajectory**. *India's Combat Air Teaming System (CATS),*[73] featuring CATS Warrior, Hunter, Infinity (HAPS) and Aerially Launched Flexible Assets (ALFA), with the US Air Force Research Lab collaborating on ALFA-S (Swarm)[74] could be flight tested in 2024.[75] Typically five LW, a recoverable version with a combat radius of 350 km and a kamikaze version with 800 km, may be controlled by a manned fighter aircraft, with the LCA as a demonstrator and later the SU 30 MKI and Jaguar as mother aircraft.[76] Equipped with AESA radar, the Warrior could launch up to 24 ALFA-S swarm drones, carry two short-range or BVR air-to-air (A2A) missiles externally, and two Smart Anti-Airfield Weapon (SAAW) in its internal weapon bay.[77] The project may later include a HALE class UAS.[78] Experiments to convert legacy manned platforms for uncrewed flying are underway.[79] Prototypes of the Naval LCA are reportedly becoming testbed for the aircraft carriers as part of the *CATS-OMCA (Optionally Manned Combat Aircraft)* project.[80] An 'Integrated Unmanned Road Map for Indian Navy' was released in October 2021.[81]

• **Global Trends in Drone Swarms**. Drone swarms are collaborative, self-organising and self-healing small UAVs (sUAV) that execute missions as a coherent whole, *with limited human control,*[82] *imposing unfavourable costs on the defender, retaining distributed combat power, even after absorbing attrition.*[83] Massed drone attacks, like on Saudi oil facilities in 2019 and Russian air base in Syria in 2018, *were not swarm attacks. Swarms are ideally suited for OCA, decoys, SEAD, LM (against air or surface targets), ISR, Air Interdiction,* *defend bases and counter-swarm missions.*[84] The US Navy's Low-Cost UAV Swarming Technology (LOCUST) program, with low endurance and slow Coyote drones, has been subsumed in the more ambitious Super Swarm project.[85] While the US OFFSET (Offensive Swarm Enabled Tactics Program) final experiment in 2021 demonstrated a single operator controlling a heterogeneous swarm of drones and UGVs in an urban setting, challenges of spatial congestion were instructive.[86] China has demonstrated a swarm of 200 drones from a 48-tube launcher from a helicopter,[87] besides larger pre-programmed demonstrations. *Israel was the first to use swarming drones in operations in 2021 to attack Hamas militants*, and is equipping infantry with swarming drones to search and attack buildings, with Legion-X, an autonomous solution that works in close collaboration with soldiers.[88] Besides these, Russia, France, Turkey, Spain, UK, UAE, South Africa and Armenia have swarm drone programs. Pakistan is seeking Chinese help to fine-tune drone swarm technology.[89]

- **India's Drone Swarming**. Following public demonstrations starting in 2021, the Indian Army has reportedly operationalised[90] swarm drones with a 50 km reach in 2022, initiated procurement of improved autonomous surveillance/strike drone swarm, including for higher altitudes,[91] and IAF has ordered a 200 drone swarm with 150 km range.[92] IAF has sought industry response for 1000+ km range collaborative swarm for long range saturation/destruction counter air missions, in dense EW environment.[93]

LEVERAGING MUM-T: LESSONS FOR THE INDIAN ARMED FORCES

- **LW.** *LW can be* a communication gateway between manned aircraft[94] and *launch smaller UAS*[95] for EW, ISR and kinetic effects.[96] The mother aircraft modification, wingman drones, the two-way data-link, radar and EO systems would need expeditious indigenous development,[97] besides rigorous development of AI algorithms.
- **Autonomous Dog Fighting- Building Trust.** Autonomous dog fighting where the *human pilot retains higher-level functions* (strategy and target priority),[98] with AI enabled UAS undertaking risky manoeuvres,[99] *would*

take long to develop, must necessarily be indigenous, must be pursued in mission mode.

• **SEAD**. The absence of UAVs for SEAD cost the Russians dear.[100] Anti-gravity manoeuvres by agile UAVs, anti-radiation LM, and decoys, would confound AD. *Experimentation for integration of* DRDO developed *Rudram series ARM* with UAS must begin post haste.

• **Electronic Warfare (EW) & Decoys**. Electronic signatures create vulnerabilities and attritable *UAS are ideally suited*, e.g. the Miniature Air Launched Decoy (MALD) and MALD-J (Jammer)[101] of the US.

• **HAPS.** Recoverable High Altitude Pseudo Satellites (*HAPS) operating from the stratosphere can* provide prolonged ISR, satellite relay/hub, EW support for MUM-T/ surface nodes, disaster management, especially in communication denied environments. Since performance challenges need to be overcome,[102] the CATS (Infinity) program of HAL (prototype in 2025) or recent initiatives with the private sector,[103] need to be expedited.

• **Swarms**. Swarms are multi-domain (land, sea and air) and demand inter-service coordination, a review of ASM, especially in the tactical battle area (TBA), and counter-measures,[104] to include EW, directed energy weapons (DEW) and lasers.

• **Drones to Substitute Critical Platforms and Provide Responsive Logistics**. *Special drones could replace* manned AWACS/AEW&C aircraft and refuellers,[105] reducing costs and vulnerability.[106] Unmanned helicopters can deliver up to 2700 kg and an unmanned glider, released from a C-130 at 25000 feet can deliver up to 750 kg of cargo across 75 km.[107] Chinese UAV AT200, operating from unpaved and uneven surfaces, can deliver 1.5 tons.[108] In contested environments, VTOL drones with ability to evacuate one or two soldiers would be critical.[109] However, physical infrastructure and ground crew of unmanned systems need reduction.[110] While logistics drones have been inducted in the Indian Armed Forces recently, the ability to operate in contested environments must be ensured.

The Future Trajectory. Future UCAVs will *be stealthier,* with advanced communication gateway nodes[111], and certified to operate in controlled space, with collision avoidance capabilities, hardened for EW. Interoperable autonomous unmanned entities would have *satellite independent data links to facilitate collaborative targeting.*[112] Unmanned transport aircraft[113] *or* HALE UAS like Grey Eagle may launch drone Eaglets.[114] Vignettes envision UAS pilots and ground forces cooperatively controlling munitions launched by each other.[115] A *multi-domain MUM-T architecture* may have *manned and unmanned multi-domain assets*, *operating as a SoS*, leveraging trusted autonomy.[116] However, the challenges of assured PNT, communication/EW hardening, interoperability, linking *varied C4I systems*, doctrines, and experimentation in AI and autonomy need to be overcome.[117] Data, pace of combat and *denied communication environment* are spurring the *development of fully autonomous systems*. Ethical concerns have been raised about Lethal *Autonomous Weapon Systems (LAWS),* which have the human out of the loop,[118] due to *non-compliance with the proportionality and distinction clauses of the law of armed conflict, and* risks arising from *hacking or software errors.*[119] LAWS must follow algorithms that obey laws of armed conflict.

TACTICAL OPERATIONS, THE AIR LITTORAL & DRONES

Salience of Drones in the Air Littoral for Tactical Operations

Territorial conflicts are won through tactical engagements in the surface domains. Operations in the *air littoral* enable an overmatch, leveraging *speed, concentration, dispersal, persistence and mass*. Though the VKS accords priority to *support to land forces,*[120] *such support has remained sub-optimal.* In contrast, *Ukraine* exploited the air littoral,[121] with reportedly 6000 drones when the conflict began. Presently, while the VKS has an upper hand in the high (operational) airspace, attrition of nearly 80% of Russian drones,[122] and similar attrition[123] of Ukrainian drones, *shows that air littoral (tactical air space), deemed salient by both sides, is highly contested*. The *air littoral* is *mostly exploited by tactical and sUAS which are organic to the surface forces, and significantly impact tactical outcomes* by leveraging agile strikes, and *most importantly by cueing surface fires. China's drone capabilities in the war zone*[124] *have been explained at length in another article in this volume*. Exploitation of the air littoral at the tactical level at scale, with a mix of drones, missiles, rocket, artillery and mortars (RAM), C-UAS and EW, and *critical issues related to this realm, need examination by air and surface forces*.

- **Deterrence through Manoeuvre in the Air Littoral**. *Conceptualisation of overt deterrence by detection for the Western Pacific is an idea with merit.*[125] Besides surveillance, imposing costs and uncertainties on the adversary with cheap and attritable drones would ensure deterrence. Notably, *mass in the air littoral enables manoeuvre, while denying it to the adversary, which in turn enables ground manoeuvre. This cross-domain deterrent manoeuvre is enabled by helicopters, massed drones, RAM, mobile SHORADS and C-UAS capabilities.*
- **Integrated Command and Control (C2) and Airspace Surveillance and Control (ASC) Frameworks in the Air Littoral**. *Generating a layered and massed* attritable force necessitates a seamless integration. Moreover, *in the air littoral,* time and space are compressed, shortening the OODA cycle. Innovative solutions like integration of the network of drones with the coalition's air space network in Iraq[126] present a model for integration *of operations in the Air Littoral.*
- ***Vertically Segmented Air Control***. *Analysts suggest* infusion of *a vertical dimension while defining air control in the trans-domain air littoral.*[127] The *drones have virtually segmented the control of air into two parallel contests-operational air control (OAC) at the higher levels*, and more localised *tactical air control* (TAC) *near the surface, impacting tactical outcomes.*[128] *In the Ukraine war, this segmentation has occurred by default, since air forces of both sides are not carrying out penetration attacks below 3000 metres in day time since a month after the war began.*[129] C2 *is progressively getting pushed to tactical levels*. Growing autonomy, AI driven target recognition, micro-munitions and shrinking costs will accelerate exploitation of drones for missions at the tactical level, *necessitating C2 and ASM at lower levels. Analysing Israel's wars since 1967, analysts have argued that air superiority does not necessarily confer decisive advantage for the ground combat*, contending that *conferring*

exclusive control of the air dimension to a single service is unsound, and tactical ground forces must be capable of independently influencing all domains that are relevant to their mission, with three *critical organic unmanned capabilities*- networked sUAS for ISR; mobile and networked SHORAD, counter-RAM and C-UAS; and UAS for critical kinetic and logistics support.[130] At the brigade level a tactical reconnaissance strike complex, a 'tactical internet of things' is visualised.[131]

- **C2 and ASC- The Indian Framework**. AD of the nation and ASC at the apex level is the IAF responsibility, excluding the AD of integral assets of the Army and the Navy.[132] The *Integrated Air Combat and Control System (IACCS) of the IAF implements ASC*, as well as *Air Battle Management*, orchestrating air operations in close coordination with other services, which requires integration with the Navy's Trigun and Army's AkashTeer.[133] AD clearance for all air movement, including in the ADIZ, is accorded by the IAF, except for very low flying army air assets within a small bubble of air space, for which flight information has to be intimated.[134] In the tactical battle area (TBA), the permission or denial of the use of air space to a user is managed through standing instructions (height bands, time slots, areas, no fly zones), and dynamic instructions to a user.[135] *What needs to be examined is whether this centralised framework facilitates decisive operations in the air littoral*? Any C2/ ASM frame work for the air littoral should *enable dynamic surface operations, service-agnostic responsive exploitation of all resources, dynamic reallocation of resources and leverage interoperability*.
- **A Drone ASM Integration Model- UTM and ATM**. The National *Unmanned Aircraft System Traffic Management (UTM) policy of 2021*[136] *addresses traffic management of drones in airspace up to 1000 feet. It advocates a seamless interoperable interface between UTM (Digital Sky) and Air Traffic Management (ATM) at the systems level, especially in the trans-boundary zone, with little human intervention, through Real-time Identification & Tracking (RIT)*. The IAF is mandated to accord AD clearance for drones through the Digital Skye interface. The Collaborative Low Altitude UAS Integration

Effort (CLUE), under validation by USAF, aims to have UAS integration upto 12000 ft MSL.

- **Integrated/Networked C-UAS**. Though navigation and communication links make drones extremely vulnerable, the adversaries will leverage *standoff, mass and attritability to enhance survivability. Detection holds the key and* integrated hybrid *systems* with EW, DEW, high-power microwave (HPM) and laser to counter cruise missiles, RAM, UAS and swarms, with a networked, multi-layered and SoS approach, *are necessary*. High-resolution AESA radars to detect and track thousands of small air and surface targets are needed at the tactical level. As part of a *warfighting concept* up to 2040,[137] the US Army is prioritising potent *C-UAS systems.*[138] *Militaries are adopting a joint approach, like the* US Army's Joint C-UAS Office and a Joint C-UAS academy.[139] The USAF *is making its Multi-Domain Control Station for Unmanned Systems interoperable with* the US Army's Forward Area AD C2 system.[140] Commercial drones *and sheer numbers will complicate identification of friend and foe (IFF),* necessitating integration of GBAD and C-UAS *capabilities at the systems level. The Indian Armed Forces and CAPFs are inducting varied standalone C-UAS systems* and there is a need to *synergise the C-UAS capability development and operational integration*.
- **Drone-Array Manoeuvre in the Air Littoral**. Organic unmanned capabilities must include relevant payloads, resilient communications, desirable autonomy and swarming. The concept of a *human controlled drone array, which can survive attrition without losing mission effectiveness, as the basic unit for air littoral operations, merits early experimentation and wargaming.*[141] *Mission tailored tactics of swarms for offensive and defensive operations at the unit/sub-unit level* can be evolved, with *the decision to use lethal force remaining under human control*. Robust datalinks, autonomous combat logistics, and other AI driven *functions will need to be developed through rigorous experimentation. Manoeuvre in the air littoral will enable manoeuvre on the surface, defying* Fukuyama's prediction[142] that drones have undermined land force structures.

BAS: OPTIONS UNDER CONTESTED AIR CONTROL

Doctrinal Precepts and Practice

The *1,000-foot air battle is an existential fight for the ground forces.*[143] CSFO include *Air Interdiction*, where enemy is *not in vicinity* of own forces, *maybe be executed independently by IAF*, and *BAS, which* engages *targets in the close vicinity of own ground forces, necessitating joint planning and close coordination with the fire and manoeuvre of own forces and integrated AD operations.*[144] *Western doctrines have similar precepts for CAS.*[145] BAS entails challenges of target acquisition, identification, enemy AD, EW, and the possibility of fratricide,[146] underscoring the role of ground and airborne forward air controllers (FAC) to enhance the mission success. Doctrinally, the *air commander must decide on the employment of air assets for BAS*, keeping in mind the overall air situation.[147] Contextually, Western CAS doctrines have provisions for *missions being placed on ground/airborne alert for 'on call AI or CAS'*, and persistent ISR,[148] *likely assuming air superiority*. The IAF doctrine holds that remotely piloted aircraft (RPA) can designate targets for BAS.[149] *Western doctrines advocate employment of combat UAS for CAS*, with a high degree of procedural coordination between air and ground forces, considering risks from friendly fires, GBAD and drones.[150] *Risk avoidance in contested environments renders BAS/CAS procedures inflexible.*[151] *There is a need to examine viable capability enhancements, leveraging unmanned systems*.

BOLSTERING BAS/CAS BY FW AIRCRAFT- SUGGESTED ENABLERS

With unmatched effectiveness against hardened targets, *combat aircraft are indispensable for BAS/CAS. However, Russia's Su-25 Frogfoot, designed for CAS, has fared poorly,*[152] *and in one year of fighting Russia has lost 50 ground attack aircraft and 44 attack helicopters in CAS.*[153] In the Indian context, *BAS has played a critical role recently during the Kargil conflict (1999)*, where laser-guided bombs were procured, to ensure responsive BAS.[154] Despite having a land-centric role, CAS by VKS has been sub-optimal,[155] due largely, to the inability to find, fix and accurately strike dynamic targets,[156] and Ukraine's contested lower airspace.[157] *Measures summarised below could improve BAS by aircraft in contested/ denied environments.*

- **Procedural Enablers**. Airborne FAC must be leveraged,[158] besides using devices that help share real time geo-tagged imagery between the pilot and ground elements.[159] Trusted relationships, a modifiable Air Tasking Order (ATO), improved shared air-ground situation, and risk-tolerant delegated C2[160] improve CAS. Providing real time airborne ISR, *bypassing higher control centers, improved CAS in Afghanistan.*[161] Adoption of *delegated C2 and flexible TTPs for CAS*, based on risks in specific tactical situations, will empower pilots and improve CAS.[162]
- **Multi-Domain Joint Fires, DEAD/SEAD**. BAS must be complemented by coordinated DEAD/SEAD, multi-domain fires, cyber and EW, and space operations.
- **Standardised Joint Training.** Certification of pilots (including UAS) is a must. Standardised joint training of FACs, Ground Liaison Officers (GLOs), staff, EW and AD/Arty officers must include ASM and coordination of joint fires.
- **Optionally Manned & Unmanned Platforms as Enablers**. Development of Optionally Manned Combat Aircraft (OMCA), such as the Jaguar Max[163] project, need to be expedited. *AEW&C sensors integrated on* an unmanned platform *could feed a manned platform at a safer distance or a ground station,*[164] *reducing the* numbers and costs.[165]
- **Stealth Aircraft and CAS**. Citing evidence that *more aircraft were hit during CAS sorties than AI sorties and improvements in modern radars, analysts argue that even stealth aircraft will be detected and their munitions countered at close ranges.*[166] *The costs and benefits thus weigh against their use for CAS.*

BAS/CAS BY ARMED/ATTACK HELICOPTERS

Doctrinal Precepts and Practice

The US doctrines uphold CAS by RW aircraft/UAS,[167] and planned upgradation of US Army *helicopters with radio links* and *Cognitive Decision-*

Aiding System will enhance interoperability during CAS.[168] In the ongoing Ukraine war, the Russian armed/attack helicopters are reportedly *exploiting darkness, attacking armour from 5-6 miles stand-off,*[169] having suffered day-time attrition. The Chinese Z-10 is night capable, with multi-purpose air-to-ground strike munitions reportedly having a range of 20 km, and drawing lessons from Ukraine, China is contemplating use drones as screens/LW.[170] The *IAF doctrine stipulates BAS missions for armed/attack helicopters.*[171] *The Indian forces operate AH-64, indigenous Light Combat Helicopter (LCH), and weapon system integrated* Advanced Light Helicopters (ALH) and it has been argued that more attack helicopters are needed, and are being procured.[172]

MUM-T Trends for BAS/CAS by Helicopters. The AH-64E Apache has fielded MUM-T,[173] the UH-60 Black Hawk can fire ALTIUS-600 family of drones[174] and unmanned recoverable/expendable swarm drones[175] are under procurement for MUM-T with future RW platforms.[176] These drones, launched from unmanned/manned rotorcraft and ground/shoulder fired systems, will detect, identify and *deliver lethal and non-lethal effects* against *enemy A2AD, C2 and logistics systems.*[177]

Lessons for India. *India is reportedly developing an unmanned Rotary UAV, based on ALH as part of the CATS program, capable of firing swarmed ALFA-S.*[178] Conceptual and technological experimentation is needed for evolving MUM-T, to ascertain attritability, autonomy and a balanced mix. The existing helicopter fleet should be made interoperable for MUM-T with UAVs in service and under procurement. *The best option is to maximise combat power in the air littoral through integrated helicopter and drone MUM-T, controlled by the surface forces.*

BAS/CAS BY UAS

Doctrinal Precepts and Practice

Western doctrines hold that combat UAS can undertake CAS and related missions in the kill-chain, Battle Damage Assessment (BDA) and counter-UAS,[179] with *control and de-confliction being akin to manned aircraft.*[180]

Western combat UAS have provided effective CAS,[181] albeit in uncontested environments. Views advocating preference of manned aircraft for CAS,[182] are equally contested.[183] *In the Indian context,* doctrines hold that remotely piloted aircraft (RPA) can designate targets for BAS.[184] It has been opined that drone swarms have a great role in *Air Interdiction or Deep Air Support, including* interdiction of targets such as command posts, communications, radars, aircraft on a ship.[185] Dynamism in C2 and ASM has been infused by the US, by creating a *Joint Air Ground Integration Centre (JAGIC) at the division level,* permitting low cost sUAS to be deemed attritable, *obviating restrictions on fires; and by adopting permissive procedural air control measures.*[186] For critical battle-spaces, JAGIC equivalents, or scalable enabled joint cross-functional teams at the brigade level, and permissive procedural controls must be examined in the Indian context.

Need for Organic Tactical/sUAS and BAS/CAS. In prolonged attritional conflicts, over time, the advantage will shift to side with more numbers. The delayed and ineffective response of grouped theatre aircraft in the 2017 US and Nigerian soldiers ambush, which underscores the *salience of more responsive organic tactical combat UAS for ground forces,*[187] *is just one of the many instances*. *In 2016,* the USAF had listed *potential benefits from 11 missions by air launched sUAS, ranging from CAS and AI, to strike coordination and force protection.*[188] Smaller, cheap LM, kamikaze and repurposed commercial grenade-carrying drones are ideal joint weapon systems.[189] *Mass and disaggregation with organic sUAS would enable more* BAS missions.

India's Growing Capability. Weaponised sUAS, LM and swarms have been recently introduced to support the surface forces. Heron (Mk2) can employ air-to-ground missiles, anti-tank weapons, bombs, and upgradation of 70 Herons with SATCOM and weapons is planned.[190] 97 Indigenous armed MALE UAVs *and 31 MQ-9B are planned to be inducted.*[191] DRDO has successfully demonstrated Stealth Wing Flying Testbed (SWiFT), a scaled down UCAV.[192]

ENABLING DRONES FOR BAS- TAKEAWAYS FOR INDIAN ARMED FORCES

- **Capability Suite**. Weapons (kinetic and non-kinetic) and sensor capabilities must enable *BAS in the Indian context, since the targets in the frontiers are underground and hardened*. SAR, laser and dual-seeker enabled weapons would be necessary. SEAD, C-UAS, EW and decoy drones would enhance BAS mission success. *High bandwidth interoperable connectivity must enable MUM-T with aircraft, to create a kill-web, enhancing BAS options manifold*. Runway independence, minimal electronic signatures, hardening, autonomous navigation and resilient beyond line of sight (BLOS) communications would be essential capabilities. Stealthy combat-UAVs would be the way forward.[193] By themselves, drones are no game changers, and *AD, EW, C-UAS systems and skilled personnel must complement drones*.[194]
- **BAS/CAS-Mission Planning and Execution**. BAS *mission planning with UAS would entail consideration of several factors like the GBAD*/C-UAS threat, weather, interoperability, communications, payloads, launch/recovery, range, altitude and endurance. ASM and integrated battle management for AD and fires are most important.[195] Extant coordination of MALE/HALE drones, helicopters, fires, EW and ASM at the Corps Air Control Centre (CACC) and the Joint Operations Centre (JOC) needs to infuse delegation and dynamism to deliver BAS in contested environments. *BAS decisions with tactical drones should be made at the tactical level, ensuring responsiveness by shortening the joint C2 chains*.
- **Kill Webs of Organic Drones and Organic Firepower of Surface Forces**. *Potent organic* precision surface fire-power is cheaper, massed and difficult to counter, well suited for responsive BAS. *The Indian land forces have lethal and precise long range rockets, guns and missiles*. Both IAF and Indian Army are acquiring surface launched Pralay missiles having 150-500 km range, with a 350-700 kg warhead.[196] Development of Guided Pinaka rockets (130-150 km) and cheaper 250 km Brahmos like cruise BAS capability is underway. *Organic and attritable runway independent drones at the tactical level are needed*

to build a kill-web to unleash the power of the organic weapons, since resources grouped or controlled at operational or higher levels are less responsive for dynamic tactical operations.

IN SUMMATION

Driven by autonomy, AI and MUM-T, drones have demonstrably accelerated the tempo of warfighting by shrinking the observe, orient, decide, act (OODA) cycle, *bolstering several critical multi-domain capability areas- situational awareness, defeating enemy A2AD, deep strikes, DEAD/ SEAD, manoeuvre in the air littoral, dynamic kill webs for the surface forces and* responsive logistics, *in contested environments,* despite their *vulnerabilities and limitations.*

21st century conflicts are witnessing a watershed moment when the exquisite platforms driven traditional doctrinal paradigm of air superiority is being debated, cheaper mass and agility driven air denial is finding wider acceptance as an operationally viable choice, the drone dominated air littoral has virtually segmented the air space into operational and tactical air control, and the surface forces are increasingly leveraging organic drones to optimally exploit organic fire and manoeuvre assets to shape the outcomes of tactical battles.

It is axiomatic that air and surface forces must examine and explore new joint solutions to the warfighting challenges at the doctrinal and conceptual level. This paper has presented arguments for leveraging drones to generate mass with MUM-T to gain air superiority; achieving air denial with LM, EW and swarms for DEAD/ SEAD; and drones as enablers. Measures have also been suggested for leveraging drones in the air littoral to further surface operations with manoeuvre in the air littoral, suggested segmented C2/ASM models, C-UAS frameworks; and finally the paper has suggested ways to strengthen BAS by leveraging drones: with manned aircraft, helicopters and organic drones, arguing for control of organic tactical drones and helicopters in this bubble to be vested with the surface forces, to maximise combat power in the air littoral.

Drones have cross-domain attributes *which necessitate real time sharing of critical information and data. Moving beyond interdependence, what is needed* *is integration*, with *flexible C2, interoperable and resilient communications, and integrated* sensor-to-shooter webs. Decentralised exploitation of drones as a MUM-T driven SoS at scale presupposes *C2 and ASM frameworks for the air littoral that optimise application of combat power and joint mission accomplishment. Evolution of concomitant air and surface warfare TTPs is equally critical*. However, it will be prudent to surmise that *the tactical, operational and strategic effects that drones deliver are necessary, but, by themselves, not sufficient conditions for victorious outcomes*.

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33-46

DRONES AND UNMANNED AERIAL SYSTEMS REVOLUTIONISING COMBINED ARMS WARFARE

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Abstract

The introduction of unmanned aerial systems has revolutionised unmanned warfare by providing drones/UAVs as low-cost, high survivability, high payoff assets for the conduct of multi-mission tasks. This has the potential of transforming multi-domain combined arms warfare, through superior integrative technology, harmonising manned and unmanned systems, doctrinal reorientation, adaptive force structuring, and above all, empowered human capital. As the Indian Defence Forces undergo structural transformation at operational and tactical levels, this critical force multiplier must find due focus in its warfighting construct.

INTRODUCTION

Manoeuvre warfare is as old as the nature of warfare and has evolved to adapt to the changing character of warfare. The revolution in military affairs with its expanding domains, proliferating players, and emerging technologies has opened new opportunities for multi-domain manoeuvre warfare. This warfighting philosophy views the adversary as an interconnected, multi-domain system, whose cohesion, if shattered, would degrade his capabilities and sap his will to resist. The contemporary multi-domain manoeuvre warfare achieves its effects in a contested integrated operational environment by the synergistic employment of manned and unmanned systems for combined arms joint force capabilities.

The combined arms concept as an integral part of manoeuvre warfare is also as old as warfare. Yet it has evolved in the 21st century as a multi domain synchronised joint force multiplier. What makes combined arms manoeuvre so potent is not the physical employment of multiple arms and capabilities in the battlespace but the cumulative and complementary multi-domain effect to generate rapidly deteriorating situations faster than the enemy can respond.[1] Combined arms warfare is less about mass and more about tempo and effects, dominating the key domain factors of time, space, force and information. Yet with multiplying domains, changing operational environments like urbanisation and multiple players cum arsenals, it has become more complex and challenging for generating desired effects.[2] The contemporary battlespace thus requires an in-depth understanding of combined arms warfare, emerging technology adaption, its redefined multi-domain application, a revitalised doctrinal construct, force restructuring and above all developing adaptive thought leaders in peacetime.

One of the most innovative technological innovations in warfare has been the introduction of unmanned aerial systems like drones and unmanned aerial vehicles (UAVs) for combined arms operations. While their primary application in a conventional war is unlikely to be for solely stand-alone operations, their combined arms force integration for multi-mission operations will revolutionise future warfare. Thus the employment of drones/UAVs as a critical component of combined arms teams for generating desired effects, at least cost and minimum time, is here to stay.

DRONE WARFARE TRANSFORMING COMBINED ARMS TEAMS

In the ever-evolving generation of nonlinear warfare, drones and UAVs have ushered in an era of unmanned revolution in military affairs. Their evolution has been revolutionised by technologies like sensors, shooters, electronic warfare, communication and now artificial intelligence, machine learning and other disruptive technologies. They have transformed manoeuvre warfare and combined arms force application by providing enhanced intelligence gathering, precision strike capability, force protection, and combat support, enabling commanders to make informed decisions faster thereby shortening the OODA loop. This in essence is the quality of "first" in the competing "kill chain".

The seamless employment of drones and UAVs has permeated the divide between war and peace, with lower escalation dynamics than manned combat aircraft.[3] As low-cost, low detection and reduced-risk systems with multi mission capabilities, drones and UAVs have ushered an era of unmanned warfare moving from counter-terrorism targeting to active war zone multi-mission application. Their lower operation and maintenance costs per flying hour as compared to military aircrafts have enabled their proliferation as a preferred option.

Furthermore, with the development of computation modules and intelligence communication systems, the battlespace is moving to an era of networked autonomous systems, also known as swarming. The development of swarming tactics, where multiple drones operate cooperatively, will further augment their effectiveness. These UAVs have integrated seamlessly into the force application matrix, adding another dimension to the way military forces plan, prepare and execute their operations.

Simultaneously investment in countermeasures has seen increasing focus. As drones become increasingly prevalent in combined arms force application, countering enemy drones and protecting friendly forces from drone threats becomes paramount. Military forces are thus investing significant resources in developing effective counter-drone measures. These measures include the deployment of advanced electronic warfare systems for jamming and disrupting drone communications and navigation.[4] Anti-drone systems employing various techniques, such as kinetic interception or directed energy weapons, are also being developed to neutralise hostile drones. Furthermore, evolving drone detection and tracking technologies for the early identification of potential threats are enabling proactive responses.

OVERVIEW OF DRONE CAPABILITIES

As technology and tactics continue to advance, drones will play an increasingly critical role in future military operations, generating more advanced capabilities.

Enhanced Situational Awareness. Drones equipped with advanced sensors, cameras, and imaging technologies offer unparalleled situational awareness to military commanders. These aerial platforms provide real-time data and imagery, enabling commanders to gather critical intelligence, monitor enemy movements, and assess the battlefield in intricate detail. The information collected by drones allows commanders to make informed decisions, rapidly adapt to changing circumstances, and exploit enemy vulnerabilities with precision. Furthermore, the integration of artificial intelligence (AI) and machine learning algorithms enhances the capabilities of drones in analysing vast amounts of data. This enables the extraction of actionable intelligence, such as identifying patterns, predicting enemy behaviour, and detecting potential threats, further augmenting situational awareness on the battlefield. AI-enabled technologies will not only increase the pace of operations but simultaneously increase force survivability in future battlespaces.

Intelligence, Surveillance and Reconnaissance (ISR). Drones play a pivotal role in conducting ISR missions, offering military forces an invaluable tool for gathering vital information about enemy positions, fortifications, and supply lines. Their ability to operate stealthily and navigate challenging terrains allows drones to access areas that may be hazardous for human personnel or difficult to reach by traditional means. By providing real-time advanced sensor feeds, such as multispectral and hyper spectral high-resolution imagery and live video feeds, drones facilitate the identification of targets and assessment of potential threats. This information assists in formulating effective strategies, planning manoeuvres, and executing precise actions while minimising risks to friendly forces.

Target Acquisition and Precision Strikes. Advancements in drone technology have led to the development of armed drones capable of carrying out precision strikes on the battlefield. Armed with missiles or other munitions, these drones provide military forces with a means to engage high-value targets accurately and disrupt enemy operations at the least cost and in minimum time. Armed drones can be employed in various scenarios, such as neutralising enemy combatants, destroying critical infrastructure, or disrupting enemy logistics. Their precision capabilities reduce the risk of collateral damage and civilian casualties, enhancing the effectiveness and legitimacy of military operations.

Force Multiplication and Operational Flexibility. Drones act as force multipliers in combined arms warfare, augmenting the capabilities of military forces and enhancing operational flexibility. By integrating drones into existing military formations, commanders extend their reach and obtain a more comprehensive operational picture. Drones can provide aerial support, monitor key areas, and relay crucial information to ground forces. They can conduct rapid resupply missions, delivering essential supplies to troops in remote or hostile environments. Additionally, drones can act as communication relays, expanding the range and reliability of communication networks on the battlefield, thereby improving coordination and synchronization of manoeuvres. This force multiplication effect allows military forces to adapt quickly to dynamic and fluid situations, seize opportunities, and maintain the initiative against adversaries. Integrating unmanned systems with manned aerial and ground systems is another evolving field. Future multi-role fighter aircraft could operate as a team with semi-autonomous drones/UCAVs in multiple roles like ISR, SEAD, targeting and exposing enemy systems, well beyond enemy detection or engagement zones of the aircraft. Similarly, UCAVs/ drones could provide another dimension to the aerial manoeuvre arm of ground forces in a space-to-surface continuum.

Combat Application of Drones in Recent Wars and Lessons Learnt. The two recent conventional conflicts namely the Nagorno-Karabakh Conflict 2020 and the Russia-Ukraine War 2022, clearly demonstrate the role of manned and unmanned teaming, and the emergence of drones/

UAVs to direct and take action against adversaries as part of combined arms warfare.[5] They have emerged as low-cost, high survivability, high payoff assets for the conduct of multi-mission tasks in both these wars. Their integration as part of a combined arms team and networks in a multi-domain environment optimised their capabilities in land, air, sea, maritime, cyber, and cognitive domains. Their fusion for a multi-layered multi-tiered integrated ISR architecture, as well as hunter shooter team was clearly visible. Further, their employment as electronic warfare platforms to degrade and destroy enemy communication and combat systems has proved invaluable. Yet UAVs and drones were seen to have terrain, weather, altitude, and persistent capability limitations, besides vulnerabilities to anti-drone kinetic and non-kinetic systems.

In Nagorno-Karabakh 2020 conflict, Armenia lost a vast track of its territory held earlier. One technological asymmetry Azerbaijan achieved was the use of unmanned aerial systems. These systems were used extensively to leverage advantage at a reduced cost, minimum time and with high payoffs. Besides combat and combat support missions Azerbaijan used An-2s as decoys against Armenian to reveal and suppress their air defence systems thereby gaining air dominance. In the initial phase which was restricted to the plains of Fuzuli and Jabrail regions, lack of cover facilitated both ISR and targeting. The use of Bayraktar TB2s for directing, targeting and strike missions in tandem with smaller UAVs like Orbiter caused heavy casualties to Armenian armoured columns. Their integration with other combat systems as part of the combined arms team proved a force multiplier. Yet the key question remained of harmonising ground manoeuvre or physical domination with such standoff capabilities as part of planning and execution of combined arms operations. During the second phase of the conflict in October, the battles were drawn into the Nagorno-Karabakh mountainous, with dense forests precluding visibility and effective application of UAVs/drones. Such close combat terrain complicated both hider finder dynamics and targeting by unmanned aerial systems. Although Azerbaijan used Turkish KARGU tactical ISR UAVs with small explosive payloads as loitering munition in this phase, their effect was not decisive. In fact, the terrain facilitated Armenia as the defender to target these systems through kinetic and non-kinetic means. The clear lesson that emerged was UAVs/drone's cost-benefit of entry into combined arms teams both at tactical and operational levels holds tremendous advantage. Further, a range of missions would require an inventory of drones and UAVs with varied add-on payloads, endurance limits and operational conditions like terrain and weather/altitude. Another lesson of the conflict was the use of UAVs and drones by both sides for information operations for domestic support and global propaganda. Overall, the conflict demonstrated the emergence of an era of networked operations and UAVs/drones as part of the combined arms team.

In the Russia-Ukraine War 2022, both sides employed unmanned aerial systems and countermeasures extensively against each other in a multi-mission mode as part of a combined arms team. Both nations used a vast arsenal of UAVs and drones for ISR, targeting and strike missions. Russia has used a variety of multi-launcher UAVs including ZALA-421, Orion, Forpost-R, Orlan-10 besides Iranian Shaheed series UAVs. Ukraine too employed a vast arsenal of UAVs, ranging from long endurance Bayraktar TB2 to smaller hand-launched tactical UAVs like Leleka-100.[6] Besides Western-aided UAVs, Ukraine also purchased some off the shelf from the financial aid provided. Their employment by both sides has been essentially for ISR and aiding targeting by air and ground combat systems as part of combined arms operations. These have been supported by networked communications, advanced mapping software and real-time downloads available to tactical commanders. Both Russia and Ukraine have also used drones and UAVs in waves for deep strike missions against ground, aerial and maritime targets. Using UAVs for information operations, decoys and deception also manifested in this war. UAVs fitted with electronic warfare payloads have also been extensively used. Unlike the Nagorno-Karabakh 2020 conflict, this conflict also saw the maturing of counter-UAV capabilities by both sides resulting in significant losses to UAVs and making their replacement a challenge. The focus had been seen to break the link between the ground controller and the

UAV. Overall, UAV/drone employment as part of a combined arms team with the redundancy of effort and a variety of platforms has matured during the conduct of this war.

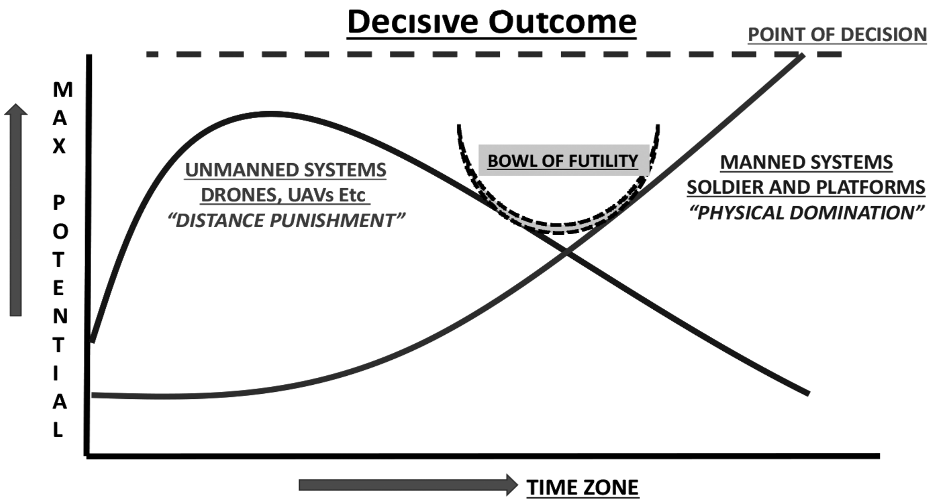
Both these wars suggest unmanned aerial systems are invaluable low-cost assets as part of combined arms teams in the future battlespace. The UAV market is projected to grow from USD 26.2 billion in 2022 to USD 38.3 billion by 2027, at a CAGR of 7.9% as per the market report. This of course would include dual-use technologies as part of civil-military fusion. As per International Trade Administration, the Indian UAV market valued at $830 million, is projected to grow at a CAGR of 14.5% during 2021-2026.[7] In FY2022-23, drone start-ups attracted $49.7 million in investments, compared to $25 million in FY2021-22 and $11.2 million in 2020-21, according to data from the research firm Tracxn Technologies.[8] Reviewed government policies have also given a fillip to several start ups in this niche capability generation.

DEMYSTIFYING UNMANNED VERSUS MANNED SYSTEMS PARADOX IN COMBINED ARMS WARFARE

The modern battlespace demands the military to cope with increasing information overload, battlespace transparency, precision munition lethality, dispersion and logistical vulnerabilities. In such a battlespace it has been proven that distance punishment by unmanned aerial systems and standoff firepower unexploited by the physical domination of ground by troops and combat systems like tanks is a wasted effect.

The traditional relationship between Distance Punishment by standoff firepower and unmanned aerial systems and Physical Domination is illustrated in Figure 1 below. It is clear that although distance punishment can be paralytic in its effect, the effect is always fleeting and transitory. Dominant manned manoeuvre on the other hand builds up and seeks the ultimate point of decision in a cost-effective and time-sensitive domain.[9] However, as illustrated a gap of futility in time and space exists between the two which provides a critical breathing space to the adversary. This is essentially when there is a lack of integration between manned and unmanned systems as part of a combined arms team.

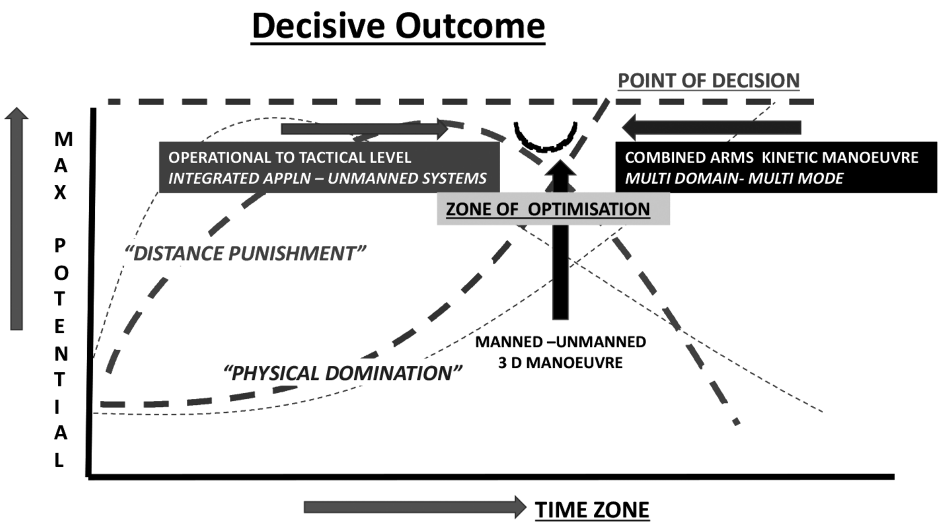
Figure 1: Unmanned vs Manned Systems



Source: Author Presentation on "Technology Empowered Manoeuvre Future Perspective", at CLAWS, April 2019.

So how do we harmonise their capabilities? Firstly we need an agile 3D manoeuvre force from the present 2D complimenting force with strategic agility, capable of generating superior operational tempo and tactical mobility for a dominant manoeuvre. UAVs/drones integrated with long-distance firepower and aerial manned systems and ground forces manoeuvre de willpack the required punch. Secondly, this capability needs to seamlessly transcend from tactical to operational level. One without the other makes neither decisive. Thus manned and unmanned systems as part of a combined arms team must function in harmony to minimise the zone of futility and maximise the zone of synergy. The same is illustrated in Fig 2 below.

Figure 2: Harmonising Unmanned and Manned Systems



Source: Author Presentation on "Technology Empowered Manoeuvre Future Perspective", at CLAWS, April 2019.

Overall, as technology revolutionises warfare with new systems such as UAVs/drones, the imperative is to integrate them with refined doctrines, structures, tactics and logistics, duly empowered by adaptive human capital to optimise their capabilities as part of a combined arms team in an essentially joint operational multi-domain environment.

RECOMMENDATIONS: INTEGRATING UNMANNED AERIAL SYSTEMS IN TO COMBINED ARMS WARFARE

The focus must be to transform the combined arms warfare capability, through superior technology, harmonising manned and unmanned systems, balanced indigenous procurement, doctrinal reorientation, adaptive force structuring, and above all, empowered human capital. The following areas thus merit focus.

- Acquire, adopt, and exploit technology in a surface-to-space continuum as part of multi-domain combined arms force application. UAVs/drones must be integrated into the combined arms team and in particular Integrated Battle Group. Training, employment procedures and logistics must be inbuilt.

- Procure a broad inventory of UAVs and drones that can operate with varied payloads, a multitude of launch platforms, operate under different climatic and operational terrain conditions, varied endurance and with technologies to be survivable in a contested battlespace. Above all hardened network communication and real-time forward download technologies and system are most critical.
- UAV/drone ability to conduct varied missions like ISR, targeting for standoff attacks, strike, electronic warfare, information operations and other missions, must be integrated into planning, preparation and conduct of operations. Technical and tactical training including wargames and exercises must find focus.
- Simultaneously counter UAV/drone measures and technologies must find focus both at the operational and tactical levels. While kinetic and non-kinetic measures must be integrated into the larger Air Defence architecture, forward troops will need to be empowered also with such counter capabilities in the tactical battle area.
- Increase the tempo and velocity of Combined Arms Forces to dominate the kill chain for desired effects and influence. Supplement manned with unmanned systems and integrate kinetic by non-kinetic strike capabilities. Proliferate from the operational level to the tactical level.
- Establish a 24×7 "Unblinking Eye" over the battlespace integrating ISR drones and UAVs in the overall surveillance architecture. Pervasive and persistent C5ISR is only possible if there is pervasive and persistent communication.[10] C5ISR will only be empowered if we shift from a platform-centric approach culture to a network-centric approach. The outcome will be a factor of networking sensors, decision-makers, and shooters.
- Adopt a centralised command, distributed control, and decentralised execution, network-enabled command and control architecture

integrating manned and unmanned systems. Proliferate UAVs and drones and distribute them downward. The lowest tactical level must be given the same relative advantage and decentralisation in superior situational awareness and precision strike capability.

- Integrate jointness and tri service interdependence to optimise the capabilities of unmanned aerial systems. Harmonise kinetic and non-kinetic capabilities in a joint force application and elevate to a new dimension of integrated command and control and seamless flow of real time information. UAVs being a tri service platform must find a tri service procurement, training, and logistics focus.
- Invest in human capital through a transformed Joint Professional Military Education. Leadership, particularly at the operational and strategic levels needs better understanding and superior orientation in executing multi-domain manoeuvre warfare. The need is for creating and nurturing strategically minded intellectual warriors, with a scientific temper as thought leaders, who demonstrate critical thinking, creative skills and technology adaption embedded in ethical military character.
- Review legacy doctrines and force structuring philosophies, with a focus on a 'capability-based approach with deterrence based on denial strategy'. Move from an attrition-centric orientation to a manoeuvre-centric orientation. Imbibe the ethos of combined arms warfare in an essentially joint operational environment.
- Optimise indigenous defence industry and start-ups for establishing a defence unmanned aerial system ecosystem along with a vibrant R&D foundation in this sector.
- Above all defence budget for new schemes like drones and UAVs must be enhanced to acquire such niche capabilities based on value and vulnerability analysis. The need is to upgrade the force restructuring philosophy from the present threat cum capability approach to the capability-based approach.

CONCLUSION

To conclude, manoeuvre warfare enabled by joint force combined arms team will be a critical enabler for prevailing in the future multi-domain operational environment. As technologies evolve and new threats emerge, harmonising manned and unmanned systems in a seamless surface-to-space continuum would be essential. UAVs/drones have emerged as part of a network of collaborative platforms and systems in a contested battlespace, an upgrade from the erstwhile standalone unilateral targeting for counter-terrorism operations. However, their effective employment for combined arms operations will require the continuous modernisation of critical components like payloads, endurance limits, sensors, and networked communications. The underlining capacity to optimise their capabilities will remain an empowered budget, trained human capital and indigenous defence ecosystem. As the Indian Defence Forces undergo structural transformation at operational and tactical levels, this critical force multiplier must find due focus.

Lt Gen AB Shivane, PVSM, AVSM, VSM (Retd) a second generation officer is an NDA alumnus and a highly decorated Armoured Corps officer with over 39 years of distinguished military service including a tenure in a UN mission. He has authored over a hundred publications on national security and matters of defence, besides two books and is an internationally renowned keynote speaker and a TEDx speaker. He is a Distinguished Fellow and held COAS Chair of Excellence 2021-2022 at the Centre for Land Warfare Studies. His book "PME for 21st Century Warriors" published in 2023.

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COMBINED ARMS WARFARE-NEED FOR UNMANNED AERIAL SYSTEMS (UAS)?

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Abstract

The focus of the paper is to establish the strategic and operational necessity for the integral employment of UAS in combined arms warfare/operations. The aim is to reach that deduction providing theoretical precepts, elaborating on systems configurations onboard, as also actual application in recent wars. The types and technological upgrades in UAS have grown exponentially, and so have their multiple missions integral to combined arms warfare. They have proved substantially impactful both in the recent 2020 Azerbaijan-Armenia war and the ongoing Ukraine war. A detailed review of their role has been attempted. UAS can perform multi-domain tasks during peace and war, ranging from domain and battlefield awareness including maritime; expeditionary operations involving extended ranges; early warning; targeting for stand-off attacks; strike on numerous military and sensitive targets; electronic warfare; Information Influence Operations; sensitive reconnaissance operations; long-loiter reconnaissance activities; tactical ISR missions using multiple sensors in a single platform for multiple missions, and act as communication hubs for numerous platforms. All this without risk to life and limb, and without overextending the mental, psychological and physical capacity and capabilities of the human resource. UASs therefore are postured to serve as a lower-risk and highly adaptable link in combined arms warfare.

After due diligence and deliberation, I feel that almost all the roles and tasks discussed in the paper will be executed by Indian Armed Force (integral to combined arms warfare), PMF, intelligence agencies, ISRO, and even security agencies dealing with the economy (ED), and logistics, with minor modifications/change in profile, drills and payloads. We too will need UAS increasingly for multifarious tasks; collect and process vast amounts of information on adversary activities as part of balance-of-power competition: across a rich variety of terrain, space and water (Indian Ocean Region). India and our armed forces have been slow starters in incorporating UASs in multi-domain operations, but I am confident that with our historical entrepreneurship and innovative skills and perseverance, we will accelerate and level the playing field with our adversaries, specially China, which has now become a strategic imperative.

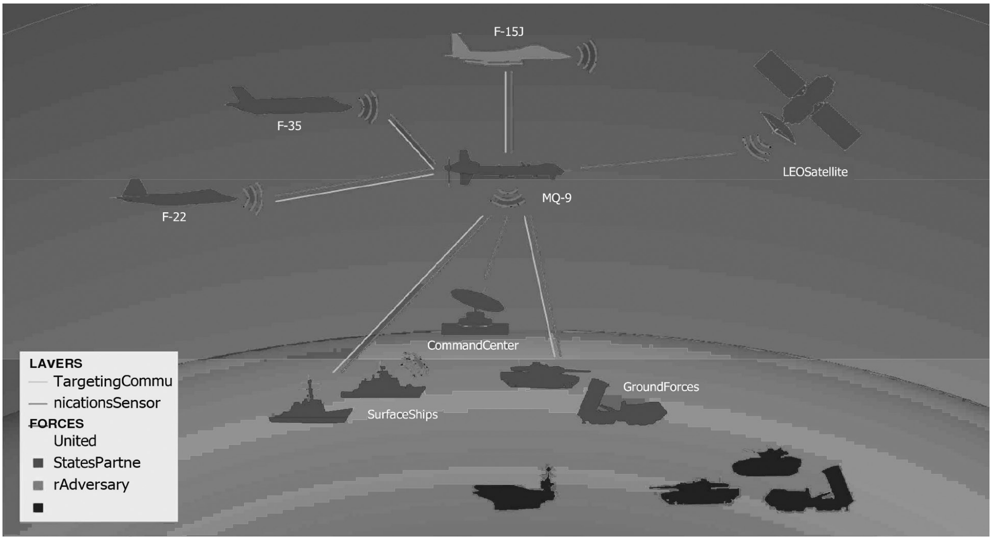
Multi-Domain Warfare (MDW): An Overview. The overlapping, progressive dimension of peace and war has moved to cooperation, competition, confrontation and conflict (4Cs) between nations; from individual military services (Army, Navy, Air Force, Amphibious Forces) to tri-Services operations, to combined arms warfare/operations, which apart from land, sea and air, includes kinetic domains of space and underwater, and non-kinetic/cognitive elements of cyber, digital, electro-magnetic spectrum and information operations; as also different types of warfare from conventional to urban, grey, counter insurgency and hybrid warfare. The spectre of a nuclear Armageddon has never been so probable. Since geo-strategic-political confrontation and conflict are both bilateral and multi-lateral, and involve nations, and not just military forces, MDW/O (Operations) to my mind, are more all-encompassing, involving combined arms warfare and the domains of politics, diplomatic, informational, military, economic (PDIME) domains. Most security especially military terminologies become ambiguous and overlapping with technological progress, inventions and innovations, hence the terms MDW and combined arms warfare are often used interchangeably. The emerging multi-polar world order is in continuous flux, with quickly changing alliances and groupings (specially security), forcing nations into 24×7 engagement. Potential threats are multi-domain-directional, dispersed, manifest suddenly without warning, and difficult to discern from the routine state and institutional behaviour. There is a strategic necessity to make sense/analyse pattern of seemingly unconnected, disparate, activities, that may be a pointer to a competitor's broader pattern of hostile behaviour, and manifests across multiple regions and multiple operating domains. Hence, the Joint All-Domain Command and Control (JADC2) concept adopted by USA, and Chinese response with Multi-Domain Precision Warfare (MDPW),[1] and India optimising and synergising the NSCS (National Security Council Secretariat) with other Ministries, Armed Forces, intelligence agencies, cyber and data watch dogs, and remote sensing platforms and institutions. USA and China are monitoring events globally 24×7, while regional power India is just getting her act together to monitor and dominate her ever-increasing sphere of influence and interest; a separate subject altogether, but today the need for a separate Security Ministry including both interior and exterior needs study. The rapid, ubiquitous emergence of the UAS specially in the last five years, allows it to perform multi-domain-tasks in peace and war, cost effectively and with a much lower risk paradigm.

Combined Arms Warfare. Combined Arms warfare in the continental context are the appropriate combinations of infantry, mobile protected firepower, offensive and defensive fires, engineers, aviation (including UAS), logistics and joint capabilities. It is the application of these combinations in unified action that allows us to defeat enemy ground forces; to seize, occupy, and defend land areas; and to achieve physical, temporal, and psychological advantages over the enemy. By synchronizing combined arms and applying them simultaneously, commanders can achieve a greater effect than if each element was used separately or sequentially.[2] Combined arms capabilities are critical to success in battle, because no single arm can be decisive against a determined and adaptive enemy. Intelligence, surveillance and reconnaissance (ISR), Information Influence Operations (IIO) and data dominance has become vital for conduct of 4Cs and combined arms warfare, as it shapes the minds, and thus behaviour of all actors of the adversary and own, including the leaders and citizens. It is important to highlight that non-kinetic/cognitive domains can cause physical destruction and causalities; rapid spreading of rumours leading to panic, paralysis and mob violence; jamming of international air and logistics circuits leading to accidents and mishaps.

UAS and Drones. The terms are used interchangeably. They are also called UAV (unmanned aerial vehicles) or pilotless aircraft. A drone/UAV is simply the aircraft or drone itself, while a UASs includes the entire system that supports and controls the drone; encompasses ground control stations, data links, and any other components like weapons, radars, jammers, cameras, communication equipment, required for the mission. The focus of this paper is on the strategic and operational necessity and employment of UAS in combined arms warfare/operations. The aim is to reach that deduction with both theoretical precepts, elaborating on system configurations onboard, as also actual application in recent wars. UAS have been playing an important role in warfare over the past three decades, mainly for counter terrorism operations, and ISR. There are two views about them amongst the experts; some feel that they have a caused a "revolution in military affairs (RMA),"which would eventually reshape military doctrine, organizations, force structure, operations, and tactics; others perceive the above attributed role as overstated, and they have limited utility in highly contested environments.

OVERVIEW OF EMPLOYING UAS, THEIR RISK AND ESCALATORY MATRIX IN COMBINED ARMY WARFARE

UAS are being employed for multiple tasks such as domain and battlefield awareness including maritime; expeditionary operations involving extended ranges (US operating in Africa, Afghanistan, Middle-East), early warning; targeting for stand-off attacks; strike on numerous military and sensitive targets including civilian infrastructure like power plants, generators as in Ukraine by the Russians; electronic warfare; IIO; sensitive reconnaissance operations; long-loiter reconnaissance activities; tactical ISR missions using multiple sensors in a single platform for multiple missions. Tasks could



Source: CSIS International Security Programme.

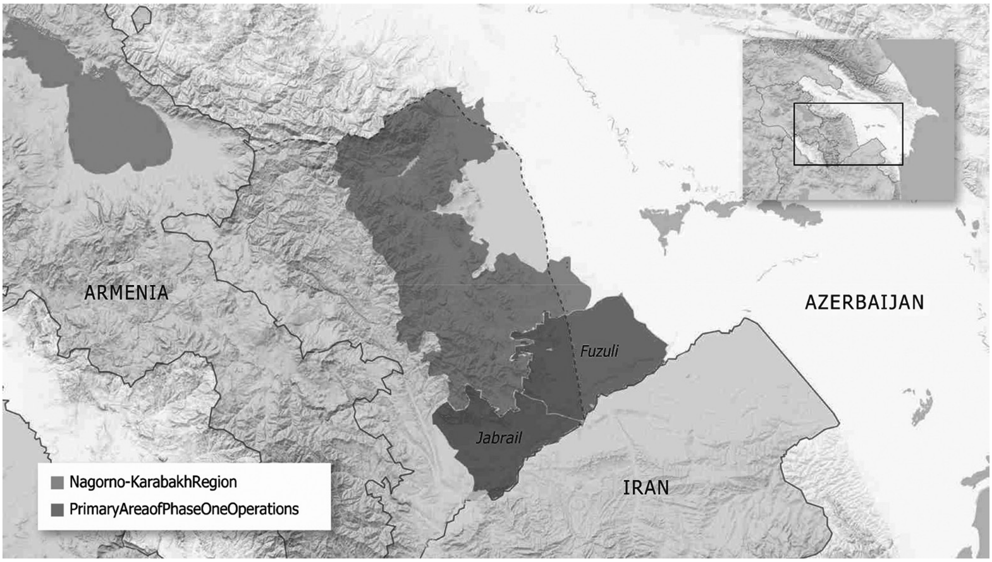
include imagery intelligence with full motion video; measurements and signals cum electronic intelligence; can collect and act as a communications hub for an integrated space, air, sea, or ground operations, while also ingesting, processing, and disseminating multiple streams of intelligence. Undoubtedly, mission flexibility is not unique to UASs. Several piloted aircraft are similarly multi-mission capable. But manned aircraft comes with risk of life and limb, and mental, psychological and physical capacity and capabilities of the human source. UASs therefore are postured to serve as a lower-risk and highly adaptable link in combined arms warfare. UAS generally present significantly lower operation and maintenance costs per flying hour than manned aircraft.[3] An important factor while tasking, is that the UAS comes lower in the escalation matrix of countries. In one 2015 example, Turkey shot down a Russian UAS that had entered its airspace, an act that did not provoke a reciprocal retaliation from Russia. One month later, Turkey shot down a manned Russian Su-24 attack aircraft, which precipitated a series of airstrikes against Turkish interests in Syria.[4] In 2019, the Iranian military shot down an American RQ-4 Global Hawk while it was operating in international airspace over the Strait of Hormuz;[5] what followed was a warning statement issued by US Air Force Central Command. ISR by satellites maybe a better discreet, secure and secret option, however, if you want to signal interest or presence, UAS conveys it better. In the military domain, this signalling may include deploying assets to demonstrate presence and commitment. Examples include naval freedom of navigation operations (FONOPS) and airborne sensitive reconnaissance operations. It is in these latter operations where the employment of UASs can substantially expand a signaller's options and ability to manage escalation in times of crisis. A natural geo-political refrain would be "We are not going to war over a Predator.[6]" A scenario, incurring the loss of an unmanned aircraft and no human lives appears to introduce a range of credible response options beyond the military domain.

UASs are increasingly part of a network of collaborative platforms and systems in a contested battle space. The figure above illustrates an UAS acting as the link to multiple platforms and systems which could include satellites; multi-role fighters; long-range bombers; aerial refueling aircraft; destroyers and cruisers; carrier strike groups; expeditionary bases; command-control-communication centres; and long-range fires.[7] To communicate across these platforms and systems, UASs need to pass information through layered networks (mainly NATO terms but all nations would need these) are tactical targeting network technology (TTNT),[8] Multifunction Advanced Data Link (MADL),[9] multiband satellite communications (SATCOM), Link 16,[10] and mesh networks.

UAS Provides Global Reach and Multi-Mission Capabilities. Emergence of a multi-polar world brings with it the need to monitor multi-domain activities and threats regionally (a reality for India today), and globally for the big two (USA and China; already happening). This involves covering large continental and maritime geographical spaces as also air, space, cyber and information domains (entire borders and IOR in case of India). There will be ever increasing requirement to possess platforms and systems capable of collecting and processing intelligence, striking targets if necessary, and operating in a contested environment.

UAS: A Natural Component for Effective Combined Arms Warfare. The broad array of missions listed above clearly illustrates the operational necessity of integration of UAS in combat arms warfare, as also the requirement of a wide variety of UAS that vary in range, endurance, operating heights, and a suite of sensors and weapon systems. Russian defense minister Sergey Shoigu had this to say about UAS, "UASs are being widely used by the Russian army to cope with a wide range of tasks. Over the past ten years the intensity of their flights has been up 7 times, and the annual flight time, 23 times."[11] The obvious response to potency and effectiveness of UAS is adopting passive and pro-active counter-UAS measures, innovations, techniques/drills and SOPs.

ROLE OF UAS AS PART OF COMBINED ARMS OPERATIONS IN RECENT WARS[12]



Source: Geodata for the Nagorno-Karabakh region is courtesy of the Europe and Central Asia Program at the International Crisis Group. See "The Nagorno-Karabakh Conflict: A Visual Explainer," International Crisis Group, https://www.crisisgroup.org/content/nagorno-karabakh-conflict-visual-explainer

NOGORNO-KARABAKH (AZERBAIJAN-ARMENIA) WAR

A historical fault line came alive when sporadic firing started in July 2020, which converted to full scale war on 27 September 2020 between Armenia and Azerbaijan, which lasted six-weeks that killed more than 6,000 combatants. Azerbaijan reversed Armenia's nearly 30-year control over wide swaths of territory in and around Nagorno-Karabakh. Ultimately, Armenia lost 75 percent of the territory it had held in these areas since 1994.[13] The war showcased the significant contribution of UASs in modern combined arms warfare, when waged even by small states; firstly, they are cost effective and pivotal in integrated battle; secondly, were used extensively in information and psychological operations; and even basic low-cost drones can be employed extensively with innovative tactics and are expendable. UAS operations in flat, low lying areas of Fuzuli and Jabrail regions were especially effective, as Armenian forces were easily discovered by ISR assets and targeted with armed UASs, loitering munitions, and artillery. As Azerbaijan Air Force gained superiority, even in the hill sector, the UAS could easily locate poorly, and insufficiently camouflaged armour and artillery locations and enemy defences, which then were neutralized by UAS, special forces, artillery and air. The aspect of counter-UAS actions needs to be highlighted, when Armenians adapted their defensive posture toward UASs, markedly improving their ability to counter these systems with traditional air defence and electronic warfare capabilities as the conflict progressed, likely with Russian assistance. However, these gains were insufficient to alter the war's trajectory after Azerbaijan's early dominance, significant attribution to UAS by all domain experts. Before events led to the war, Azerbaijan invested heavily in Israeli UASs. At the outbreak of the 2020 war, Azerbaijan's inventory included at least seven different categories of Israeli unarmed UASs and two categories of loitering munitions.[14] In mid-2020, Azerbaijan acquired its first armed medium-altitude, long-endurance UAS, Turkey's Bayraktar TB2 (5). While the TB2 emerged as perhaps the most prominent capability deployed during the war, available evidence suggests it is likely that the TB2s used in the 2020 war were owned by Azerbaijan but operated by Turkish airmen and crews.[15] One other Turkish system, a portable rotary-wing loitering munition known as the KARGU, was used by Azerbaijani special forces in mountain combat against Armenian forces.[16] The KARGU is a portable, rotary-wing tactical drone with ISR capabilities and a small explosive payload.[17] The inability of Armenian air defenses to combat Azerbaijani UASs is well documented. Many of Armenia's air defenses, including the OSA, Krug, and Strela-10, were of Cold War vintage. Armenia had acquired more advanced capabilities, including the Russian S-300, Buk, and Tor-M2KM, but these systems were not effective at countering small, low- altitude threats such as Azerbaijan's UAS fleet.[18] Azerbaijan's operations in these southern regions in the first two weeks of the war reflected a combined arms approach that integrated multiple armed and unarmed systems, loitering munitions, guided missiles, and artillery. Videos and imagery of Azerbaijani operations in these regions show Bayraktar TB2s being utilized for both targeting and strike, operating in tandem with lower-altitude, smaller UASs, such as the Israeli-manufactured Orbiter, as well as other ordinance delivery mechanisms.[19] Overall, the integration of multiple UAS sensors with various weapons, including missiles, loitering munitions, artillery, and other fires, indicated that their cost of entry for advanced combined arms warfare is declining.

IIO and Cost Benefits Using UAS. UAS were extensively used for IIO. By the first day, Azerbaijan posted multiple videos each day of raw drone footage of air and artillery strikes. The primary purpose of this propaganda was likely to solidify domestic public support for the war and the ruling dispensation, as also degrade morale of adversary's armed forces and public. The Azerbaijani government played combat footage on large monitors on public display in Baku. Russia and Ukraine both are repeating it, with Ukraine hoping to further galvanise NATO and international support. None of Azerbaijan's drones cost more than 20$ mn (in fact some as low as 1$ mn, including the TB2) and could be bought and employed in bulk, proving extremely cost effective.[20] A very apt employment is Azerbaijan's use of the Antonov An-2; a single-engine biplane originally manufactured in 1947. In advance of the 2020 war, Azerbaijan retrofitted numerous An-2 aircraft with remote piloting capabilities and added armaments to some. This allowed Azerbaijan to conduct effective suppression of enemy air defences (SEAD) operations using an outdated, expendable airframe.[21] An-2s were deployed as bait against Armenian air defences (AD), and very often the Armenian AD engaged the An-2 to shoot it down, resulting in them exposing their positions, leading to their neutralisation by UAS and other resources.

THE UKRAINE WAR

The deployment and employment of UASs surged exponentially during the Ukraine war as part of combined arms warfare. There is no dearth of videos, written or spoken material on the internet. UAS have been deployed in multi-task-mission mode extensively, employing one or multiple/ swarm UASs. All tasks enumerated at the start are being executed in this war. Because of the effectiveness of UASs, Russia and Ukraine have also developed counter-UAS tactics, techniques, and procedures. The Russian offensive started with them using UAS as decoys to expose Ukrainian radars and air defence systems. These actions facilitated an opening salvo of missile strikes, including from Kalibr cruise missiles and Iskander systems, on Ukrainian AD.[22]

EMPLOYMENT ILLUSTRATIONS AND MAJOR LESSONS

A new term “kill chains”, has emerged which is the process of gaining an understanding of the battlefield, identifying a possible target, determining the target’s location and other pertinent information, deliberating what action to take, and making a decision that creates an effect to achieve an objective (such as conducting a strike).[23] The Russian military has long identified UASs as playing an important part of its “reconnaissance strike complex”, which is designed for the coordinated employment of high-precision, long-range weapons linked to real-time intelligence data and accurate targeting.[24] Russian forces have used a variety of UASs and loitering munitions in Ukraine, including the Orlan-10 and 30, Forpost-R, Eleron-3, Granat-1 and 2, Israeli Zastava, mini UAS Takhion-4, Orion, and loitering ammunition ZALA-421. Russia has also imported UASs from Iran, including the Shahed-131 and Shahed-136.[25] The short-range Orlan-10, launched by folding catapult, has been the most widely used UAS in the Ukraine conflict and is the most numerous in Russian military service. Each Russian land force division and brigade has an organic UAS company equipped with Orlan-10s, and Russia possessed around 3,000 Orlan-10s before the war.[26] They were developed for such missions as aerial reconnaissance, electronic warfare, detection of radio signals, target tracking, observation, and monitoring. It can accommodate photo and video cameras, a gyro-stabilized TV camera, and an infrared imager.[27] Russia's For post-R, which was developed by Israel Aerospace Industries as the Searcher Mk II (in service with Indian Armed Forced less the weaponised version), is capable of reconnaissance and strike and is equipped with indigenous software, datalinks, electro-optical sensors, an APD-85 piston engine, signals intelligence sensor packages, and a reinforced fuselage for additional survivability.[28] It includes ground control stations, antennas, and logistics support equipment. The Eleron-3, a small, tactical delta-wing UAS has been mainly used for ISR.

Ukraine has been operating several types of UASs.[29] Once again, the Turkish Bayraktar TB2, has been in the forefront. It performed a range of ISR and attack missions, including firing MAM-C and MAM-L guided bombs, long-range anti-tank missiles, Cirit laser-guided 70-mm rockets, and TUBITAK-SAGE laser-guided rockets. Ukraine also operated small A1-SM Furia flying-wing UASs for day and night reconnaissance; hand-launched Leleka-100 and Spectator-M mini-UASs for artillery spotting and aerial reconnaissance; the Punisher UAS produced by UA Dynamics were used to strike military targets; and larger indigenously produced PD-1s and UJ-22s.[30] Ukrainian forces have utilized off-the-shelf commercial UASs, such as DJI Mavic 3 quadcopter, which has a retail price of roughly $3,000. In some cases, Ukraine has manufactured UAS parts with 3-D printers.[31] In addition, the United States has provided several loitering munitions to Ukraine, such as the tube-launched Switchblade 300 (with an Orbital ATK high-explosive warhead) and the long-endurance Phoenix Ghost.[32] The Phoenix Ghost, for example, is a tactical loitering munition that can fit inside a backpack, hover over a target for approximately six hours, and strike it with an explosive munition. It has infrared guidance and can operate at night.[33]

ELABORATION OF EMPLOYMENT IN SPECIFIC ROLES

- **Domain Awareness:** This task has always been the mainstay of UAS so far, but expansion of domains has been exploited during the war. The sensors on Russian and Ukrainian UAS platforms have collected signals intelligence, videos, and other information for operational use by ground, air, and maritime forces. UASs can carry photo and video cameras, a gyro-stabilized television camera, an infrared imager, and signals intelligence sensors (including direction finders).[34] These capabilities have also allowed UASs to be useful for post-strike battle damage assessment (PSDA). Similar to 2020 war, both have used UAS as decoys. Russian started their special military operations deploying decoys, while there are indications that Ukraine has used Tu-141 UASs as decoys for similar purposes.
- **Target Identification and Fixation.** UASs used extensively to identify and fix targets for artillery and aircraft as part of combined arms operations. In one operation, Ukrainian ground forces used forward-deployed UASs to identify a Russian infantry unit near Bakhmut in Donetsk, Oblast and fed the information to a command and control center, which passed it to Ukrainian soldiers that hit the Russian unit with a 122-mm howitzer.[35] Ukrainian forces have utilized Kropyva, an intelligence mapping and artillery software populated by information from UASs and other sources. Forward-deployed tactical units have downloaded the software and continuously updated it on handheld tablets and computers. Ukraine has leveraged Starlink, a commercially owned (Elon Musk) satellite internet constellation that provides high-speed, low-latency broadband internet using advanced satellites in low

earth orbit for identification. As one Ukrainian military official noted, "We use Starlink equipment and connect the drone team with our artillery team. If we use a drone with thermal vision at night, the drone must connect through Starlink to the artillery guy and create target acquisition."[36] Russians have employed Eleron-3 or Orlan-10 UASs to identify potentially targets, such as Ukrainian C3 centres, infantry or main battle tanks; pass the information, including the type of target and its coordinates, to command and control facilities; and distribute it to systems that can strike the target, such as 2S19 Msta-S 152-mm self-propelled howitzers or Tornado-S 300-mm multiple launch rocket systems, as fast as within 3 to 5 mins, while with electronic warfare direction finding, acoustic reconnaissance, or counter-battery artillery radar, it might take Russian artillery half an hour for accurate artillery fire. If Russian forces are able to keep a UAS on a target, they can adjust fire in near real-time, even if the target is moving.

- **Strike.** Russia and Ukraine have utilized UASs for strike missions, including against land, air, and maritime targets. Ukrainian Bayraktar TB2 drones have struck numerous Russian targets, such as howitzers, main battle tanks, supply trucks, towed artillery, maritime vessels, command posts, logistics depots, and Buk, Tor, Strela, and ZU-23 air defense systems.[37] Illustrating UAS deployment in multi-domain environment, between April 26 and May 8, 2022, Ukrainian TB2s targeted several Raptor-class patrol boats, a Sarna-class landing craft, and helicopters in and near the Black Sea.[38] Russia has also conducted strikes with UASs, including Orlan-10s armed with freefall high-explosive fragmentation grenades. Russian forces have also utilized Iranian Shahed-131 and Shahed-136 UASs to strike targets deep inside Ukrainian territory. These types of UASs posed challenges for the Ukrainian military because they can fly at low altitudes that make it difficult for air defences to detect. In October 2022, for example, a Shahed-136 struck a Ukrainian military headquarters roughly 50 miles south of Kyiv, causing significant damage to the facility and surrounding infrastructure.[39] Raising global apprehensions, as recent as May/June 2023, Kviv used UAS to strike wealthy districts of Moscow.[40]

- **Electronic Warfare (EW).** Both utilized UASs for EW. For example, Russia has used RB-341V Leer-3 electronic warfare payloads mounted on Orlan-10 UASs to target Ukrainian cell phone networks. More broadly, Russia has utilized UASs, such as the Orlan-10, to jam GSM 900, GSM 1800, 3G, and 4G signals within a radius of roughly 6 kilometres. Russian units have also utilized Krasukha-S4 electronic warfare systems to take down Ukrainian UASs.[41] Effective use of electronic warfare can cut off drone pilot communications, interrupt live video, or force systems to crash or retreat. In response, Ukraine has attempted to counter Russian electronic warfare, such as by using a radar-homing seeker payload for explosive-laden UAS. Since most electronic warfare complexes take between 25 to 40 minutes to set up, forcing displacement can be an effective means of suppression that, in turn, can create windows of opportunity for Ukrainian UASs and reconnaissance teams to communicate the position of Russian systems in real-time and determine the exact coordinates of positively identified targets.[42]
- **IIO.** Extensively employed as visuals of drone strikes from both sides are flooding social media platforms like YouTube, Twitter, Telegram, and TikTok. UAS surveillance has also provided high-quality imagery of ground engagements that is reminiscent of video games.
- **Counter-UAS Activity.** The high intensity and highly effective combined arms UAS employment led to concrete steps by Russia and Ukraine to develop and execute counter-UAS tactics, techniques, procedures, and capabilities (both passive and pro-active); which are constantly evolving, specially efforts to break the kill chain between the operator and the UAS. Both nations have suffered high rates of attrition. Many have been shot down on the battlefield or have been subject to electronic jamming. TB2s and Russian Orlan-10 and For post have been vulnerable to air defense systems, air attacks, and EW because they are slow, large, low-flying, and radio-controlled. Russia has used the Shipovnik-Aero, a truck-mounted

jamming system with a range of 15 kilometres optimized for targeting UASs. The system has detected UASs through their control frequency, analysed and reconfirmed the information, and jammed the command frequency. The system has also been used to override the position of the UAS so that return-to-base protocols lead the UAS to land in a location designated by Russian forces.[43] Employment of various early warning and air defence radars used for UAS detection, and EW radars to jam and disrupt their communications; while to target UASs and ground control stations, Russian forces have used machine guns, air defense systems, such as the Tor missile system, 152 mm howitzers, 300-mm multiple launch rocket systems, and Tochka-U systems. Russian successes over time in targeting Ukrainian UASs have led to a lifespan of roughly seven days for a Ukrainian UAS.[44] Ukraine has followed suit, and has maintained organic man-portable air-defence teams, sometimes equipped with visually guided systems, such as Starstreak and Martlet, to target UASs. However, as UASs become more autonomous and less dependent on GPS, jammers will be less effective.[45]

- **Suppression of Artillery Fire.** Russian forces assessed that Ukrainian "UASs, high-precision loitering, and artillery ammunition and communications equipment rely on positioning through the reception of signals from satellite radio navigation systems."[46] Learning from above, they instructed own forces to continuously suppress access to satellite navigation through regular operation of the Pole-21 system and the R333Zh, both on maximum power using omni-directional jamming. They realised that the impact on command and control could be limited by linking command posts by ground-laid field cable. Both the Pole-21 and R330ZH systems were turned off prior to the initiation of Russian artillery strikes that might require accurate satellite-based positions.
- At cost of repetition, minimal risk to human life is associated with UASs; risk increasing exponentially in heavily contested air space widens like in Ukraine.

UAS LOST BY PLATFORM TYPE

UAS Type	Number Lost	UAS Type	Number Lost
Military Forces of Russia	169	Military Forces of Ukraine	41
KBLA-IVT	1	Athlon-AviaA1-SMFury	4
Enix E95M	3	DeViroLeleka-100	3
Enix Eleron	10	Spaitech Sparrow	1
For post-R	3	TB2	11
Kalashnikov Group KUB-BLA	1	Tupolev variants	5
Kronstadt Orion	1	UkrjetUJ-22	1
STCOrlan variants	101	Unspecified loitering munition	1
Izhnash Takhion	2	Unspecified VTOLUAV	1
ZALA421-16E2	3	Unknown	14
Unspecified reconaissance drone	2		
Unknown	42		

Source: CSIS analysis using data from open-source websites ACLED and Oryx. Data collected runs only from February–May 2022.
Note: the NYT of May 23, 2023 quotes loss of 10000 UAS per month.[47] EurAsian Times writes of Russia smashing 337 UAVs per month; both due to electronic warfare.[48]

US Developing and Testing Advanced Communication Packages. Ever since the Nogorno-Karabach war, USA and NATO has extended special focus to employment of UAS in combined arms exercises. Exercise Northern Edge 21 was one such exercise involving US Indo-Pacific Command (INDOPACOM), with a pivotal task of test bedding advanced UAS packages.[49] The primary UAS integrated was the MQ-9 Reaper, including the so-called "Ghost Reaper," with upgraded communications packages and machine learning capabilities. The modifications and modernizations include new sensors and anti-jamming capabilities, which will be better suited for strategic competition and major power threats.[50] The MQ-9 Reapers integrated at least four new payloads. The first is the Reaper Defence Electronic Support System (RDESS), which "collects and geo-locates signals of interest from standoff ranges", and allows the MQ-9 to conduct ISR operations and precision targeting at a sufficient standoff distance from the target to avoid enemy countermeasures. The RDESS with additional electronic countermeasures, enhances the survivability of the existing MQ-9 airframe.[51] The second and third new payloads facilitate communications and data flows consistent with the "sense and integrate" pillars of the JADC2 strategy; enabling communications interoperability across different protocols and radio networks; probably stopgap solutions before achieving machine learning and integration.[52] The final new payload is the MQ-9 Centerline Avionics Bay (CAB) pod, designed to integrate high-performance onboard computing capability for processing sensor data onboard the aircraft. Continuous modernization across tactical sensors in the air, space, sea, and land domains will result in these battle networks collecting larger and larger quantities of data.

HIGHLIGHTING SOME PIVOTAL LESSONS LEARNT

- '**Survivability in Contested Airspace'.** Achieved by increasing standoff distances; reducing exposure to air defences; hardening the existing systems to with stand communications jamming and other electromagnetic attacks. Sensitive and vital targets will always be worth the risks and attrition.
- **'Nodes in an Integrated Battle Network'**. Ingesting data from air, land, sea, space, and cyberspace and relay this data back to decision makers and joint fires.
- **Multi-Mission ISR Capability**. Includes cognitive inputs like signals intelligence, electronic intelligence, measurement and signature intelligence, imagery intelligence collection, the latter needing full motion video and hyper spectral, multispectral, and synthetic aperture radar packages.

EMPLOYMENT OF UAS IN COMBINED ARMS OPERATIONS IN THE INDIAN CONTEXT

Wars, confrontations and multi-domain strategic and operational global crisis situations, and military exercises in just the last five years, has convincingly showcased the necessity of integrating and possessing integral UASs for combined arms warfare. It does not require rocket science to deduce that India needs to integrate them for conduct of MDW. With our regional power status, ever-increasing strategic space, and expectations of the global powers and Global South, India has to urgently surge her UAS capacities and capabilities. With our boundary disputes against collusive China and Pakistan, and fickle immediate and regional neighbours; against the backdrop of a belligerent hegemon China, 'the innovative employment of UAS in multi-domain operations will keep us in contest and prove a game changer. Our contentious, active borders along high-altitude Northern borders and LC, coupled with increasing interventions by adversaries in the IOR, dictates the mandatory integration of UAS. Enhanced employment in counter-infiltration-terrorist operations will remain a key imperative. UAS role and potency in conventional and hybrid confrontation and conflict/ wars has been discussed in detail, and will not be much different for India. After due diligence and deliberation, I feel that almost all the roles and tasks envisaged above will be executed by Indian Armed Force, PMF, intelligence agencies, ISRO, and even security agencies dealing with the economy (ED), logistics et al., with minor modifications/change in profile, drills and payloads. We too will need UAS increasingly for multifarious tasks; collect and process vast amounts of information on adversary activities as part of balance-of-power competition: across a rich variety of terrain, space and water (Indian Ocean Region). We need UASs that can operate with extended range, multiple-payloads, and latest system packages to contest current and future confrontationist environment. UAS intrusions from China and Pakistan are a reality and occurring with increasing frequency and regularity. We need to train and adopt counter-UAS tactics as discussed, in response to the proliferation of UASs.

CONCLUSION

UASs are playing a dominant role in multiple domains during peace and war. They have been particularly valuable in a contested environment without risking loss of life. It is too early to pass judgement on those who feel that role of UAS is overstated, and those who feel that UASs have brought about a 'revolution of military affairs' and in conduct of warfare. One thing is certain; UAS will gain increasing prominence and pre-eminence in MDW during the entire competition-confrontation-conflict stages. Recent wars specially the Ukraine war has cemented the inescapable employment of integral, interconnected, multi-role UASs in combined arms warfare; and has brought significant payoffs to the side which employed it most optimally and innovatively. India and our armed forces have been slow starters in incorporating UASs in multi-domain operations, but I am confident that with our historical entrepreneurship and innovative skills and perseverance, we will accelerate and level the playing field with our adversaries, specially China, which has now become a strategic imperative.

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PLA'S UNMANNED VEHICLES' EMPLOYMENT IN WESTERN THEATRE COMMAND

Brig Anshuman Narang

Abstract

China, since the Doka-La standoff of 2017, has intensified the multi-domain employment of drones or Unmanned Vehicles (UVs) in People Liberation Army's (PLA) Western Theatre Command (WTC). The Yemen, Syrian, Libyan, Azerbaijan-Armenian, and Russo-Ukrainian conflicts have been watched closely by the Chinese military scholars to adopt the lessons learnt to transform the employment of drones by PLA. These lessons have been incorporated by WTC in integrating the UVs in their latest Layered Border Defence Strategy since Eastern Ladakh standoff of 2020. The daily PLA news magazine, accessible at www.81.cn, never has had a week go by without an article addressing the conceptual contours of drones' employment for Multi-Domain Precision Warfare (MDPW) or Multi-Domain Integrated Joint Operations (MDIJO). This paper shall thus focus on WTC's induction of variety of PLA's multi-domain UVs and its combat variants (UCVs). The term UVs in this paper will encompasses all varieties- Unmanned Aerial Vehicles (UAVs and UCAVs), Unmanned Under-water Vehicles (UUVs), Unmanned Ground Vehicles (UGVs and UGCVs), multi-disciplinary Swarms (an acronym for Smart Warfighting Array of Reconfigured Module), loitering munitions and Robotic Autonomous Systems (RAS) or Robotic Combat Vehicles (RCVs).

INTRODUCTION

> "Now, there are a large number of drone system and unmanned operations are profoundly changing the face of war. It is necessary to strengthen unmanned combat research, strengthen the professional development of drones, strengthen practical education and training, and accelerate the training of UAV use"
>
> -Xi Jinping, Visit to Air Force Aviation University on 01 August 2022

PLA's 'Three Modernisations' concept encompasses the evolution from Motorisation to Mechanisation and from Digitisation to Informatisation and Intelligentisation. Since Intelligentisation is focussing on the induction of multi-domain drones, autonomous systems, and their combat variants, it is facilitating 'Autonomisation' and will get further strengthened by Quantumisation. PLA's infusion of the next most important technology 'Quantum', will make its UVs stealthier, more disruptive with stronger algorithms, precise with secured communication and fastest processing speeds.

Military drones are a very important part of Xi's PLA's "new domain and new quality combat force". The expenditure on them exceeded 19.3 billion yuan in 2022 for all domains – aerial, surface, underwater and land.[1] Apropos, Communist Party of China (CPC) Chairman Xi Jinping's 'Whole-of-Nation Approach' (WONA) has been very effectively applied towards employment of drones through civil-military fusion (CMF). The induction of UVs in PLA has happened across all arms and services at all levels as illustrated by at Figure 1.

This paper will appropriately cover the critical issues of PLA's employment of UVs in WTC under the heads of PLA's lessons from recent conflicts, UVs induction at various levels, infrastructure development to support drones' deployment for layered border defence strategy, likely employment contours in support of WTC's MDPW and MDIJO and finally implications.

Figure 1: Chinese Whole-of-Nation Approach for Drones Induction

Users- PLA's Theatre Commands	Users - PLA's Special Services	Users - Civil Organisations	Key Drone Production Companies
•PLA Air Force (PLAAF) - UAV Brigades & Airborne Brigades •PLA Ground Force (PLAGF) -Border Defence Regiments / Brigades, Combined Arms Brigades (CABs), ISR & Other Specialist Brigades •PLA Navy (PLAN) - UAV Brigades	•Strategic Support Force (SSF) •PLA Rocket Force (PLARF) •Joint Logisitcs Support Force (JLSF) •People's Armed Police (PAP) including China Coast Guard (CCG) •Militia	•Border Immigration Police •China Meteorological Administration •Logistics Delivery Companies •Driver-less Taxis / Buses •Fire Fighting Department •Local Governments •Provincial Police Departments	•China Aerospace Science & Technology Corporation (CASC) •China Aerospace Science and Industry Corporation (CASIC) •Aviation Industry Corporation of China (AVIC) •Chengdu Aircraft Industry Group (CAIG) •Sichuan Tengden Technology Corporation

Source: Author's Research for Three Books.

PART 1: LESSONS FROM RECENT CONFLICTS

"Forethought leads to success, and lack of forethought leads to failure"

– Huang Bin, Former Chinese Defence Industry Executive[2]

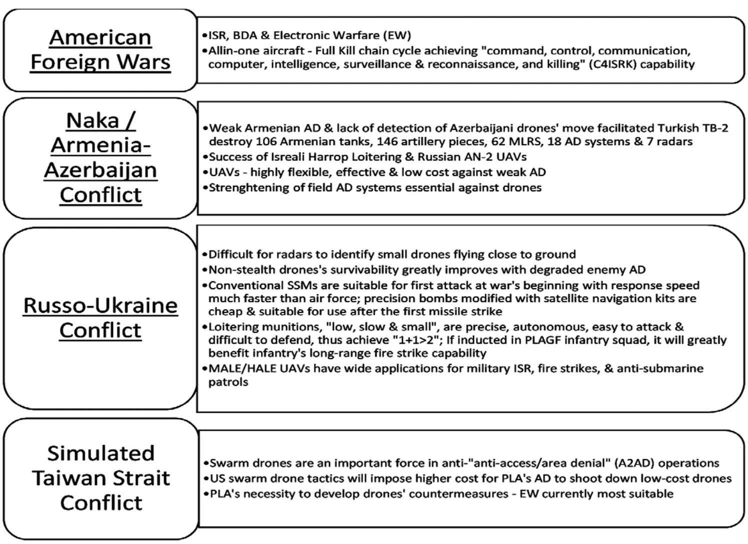
While earlier conflicts particularly by US in Iraq and Afghanistan and Russia in Syria and Crimea witnessed one-sided employment of drones, the Turkish combat operation "Spring Shield" against Syria, the Armenian-Azerbaijan's Nagorno-Karabakh conflict in 2020 and the ongoing Russo-Ukraine conflict has truly operationalised the much talked about drone warfare. The swarm warfare seems just another war away. The success of Turkish Bayraktar TB2 UCAVs and Iranian Shaheed Loitering Munitions, and extensive employment of Chinese civilian DJI drones has provided important military lessons in the employment of UVs particularly for PLA. Even the Eastern Ladakh standoff has had many lessons for PLA particularly for border patrols and logistics provision through drones in difficult terrain areas obtainable in WTC.[3]

Chinese Military websites in the past three years have been swarmed with news about these conflicts with clear focus on lessons learnt from tactical to strategic levels. The Chinese netizen accounts are flooded with daily dose of photos of Ukrainian drones entering Moscow, destroying Russian tanks or vice versa. As the conceptual development battle between drone and anti-drone systems, technologies, and tactics progress like a cat-mouse game and get battle-tested, PLA's multi-tiered drone combat units are effectually drawing out their lessons.

A latest in-depth report on Military UAV Industry released by China in June 2023 has adequately highlighted the summary of lessons learnt as elucidated below:[4]

- The advantages of employment of drones lie in their operational flexibility and low energy consumption, while the disadvantages lie in information and intelligence provided to the enemy.
- UAVs have undoubtedly become indispensable and thereby the "darling" of modern intelligentised battlespace, and their application scenarios are expanding and will continue to do so. The key employment concepts derived by various countries in recent conflicts from Chinese perspective are elucidated in the info graphic below.

Figure 2: UAVs Employment Concept Evolution from Chinese Perspective



Source: Chinese 2023 Military UAV Industry In-Depth Report.[5]

- Drones are the most effective tool in unilaterally completing six stages of battle-space kill chain from finding, fixing, and tracking to targeting, engagement, and assessment (F2T2EA). As per Chinese analysis, the US has achieved a drastic reduction from 80 to 101 minutes in the first Gulf War to just 20 seconds in 2020 in Afghanistan.

Figure 3: Kill Chain Cycles' Temporal Reduction by US Through UAVs

Source: Chinese 2023 Military UAV Industry In-Depth Report.[6]

- UCAVs and Combat UVs, i.e., those UVs with integral surveillance and strike capabilities, are the general trend of development of military UVs/ UAVs in any battlespace domain, particularly for hunting time-sensitive targets (TSTs) by surprise.

Figure 4: UCAVs Generational Evolution

UCAV Genration	US	PLA	Key Feature
1st Generation	MQ-1, Predator	CH-3, CH-4	Turbo-charged Engine
2nd Gneration	MQ-9, Reaper	WL-2, CH-5 (10,000 km, 120 hours), WZ-7	Small size, high power Turbojet engine
3rd Generation	Avenger	WL-3, CH-10, WZ-8	High-altitude, speed & stealth

Source: Chinese 2023 Military UAV Industry In-Depth Report.[7]

Mixture of Small and Large Drones. The Turkish TB-2 drones which were the star performers in the Azerbaijan-Armenian War succeeded initially in the Russo-Ukraine War. However, as the war progressed ahead, it became very dangerous for medium and large surveillance drones like Turkish TB-2 drones and the Russian Orion drones to survive in presence of intensely dense Air Defence (AD) systems in the battlespace. The induction of drones at the lowest military echelons, whether purchased commercially off the shelf or provided by third nation,[8] enhances credible offensive capability against a stronger and technologically capable adversary. Apropos, PLA scholars realised that it was the small loitering munitions like the Iranian Shahed, American Switchblade and Lancet that succeeded alongside the civilian small and micro drones such as shuttle machines. Hence, PLA has decided to focus on a balanced combination exploiting the stronger survivability of small and micro drones at team/sub-unit level and the enhanced power, larger payload and ammunition capacity and resultant greater penetration depth of medium and large UAVs at higher level. While this balance needs to be maintained by the induction of all varieties of drones in PLA, the mother-child or marsupial drones concept allows both advantages to be exploited simultaneously.[9]

Masking. Azerbaijani's new drone tactic called 'Masking' has been analysed in great depth by PLA's scholars. In order to deceive and destroy the Armenian anti-drone system Repellent (Russian procured), Azerbaijanian drones managed to hide behind other means of electronic warfare of its army. The US military had used the same 'masking' tactics in Chinese airspace, from PLA's perspective, by hiding a reconnaissance plane behind a civilian plane.[10]

Runway Repairs. The US wars in Iraq made PLA realise the importance of rapid runway repairs. Hence, PLA incorporated the cheapest method of runway repairs by incorporating local militia organizations which are located close to its airfields. The PLA has signed many agreements with local civilian construction companies with requisite experience to reestablish PLAAF airfield's operability thus enhancing resilience. The

WTC Air Force has organised multiple such exercises, like 15-day training event with over 150 militiamen divided in 10 local militia's engineering repair units, for clearing the runway of smoke and damaged runway sections.[11]

CMF - Use of Civilian Airports. In April 2018, the Tibet Regional Bureau, and the WTC PLAAF's Lhasa Base held a meeting at the Gonggar Airport to establisha Leading Group for the Deep Integration of Military and Civil Aviation at Lhasa and Shigatse Airports. The two sides reached a consensus on six issues for deep integration in coherence with the CPC's General Secretary Xi's overall national security concept and strategic thinking on border governance and Tibet stability. The WTC PLAAF Lhasa Base Commander Cai highlighted that all the Tibetan airports are military-civilian, with unique advantages in terms of geographical environment and for national defence security. To strengthen CMF, the two sides decided to integrate and build airports together with high standards and strict requirements to complement each other's advantages.[12]

The exercises by WTC's PLAAF in June and July 2021 indicated their inclination to introduce aircraft landings at "unfamiliar" airfields, thereby enhancing combat optionsto use civilian airports whenever battlefield circumstances dictated the same. The PLAAF's 9th Engineering Corps has furthermore built nearly 110 airports in WTC accounting for 90% of the high-altitude projects in the mountainous provinces like Tibet and Xinjiang.[13] The planned construction of 58 airports in Tibet by 2035 and 33 airports in Xinjiang by 2033 are all steps in this direction. The Tibet Aviation Development plan has prioritised development of Unmanned industry as shown in Table below. These civilian unmanned flights can be used for military roles from ISR to logistics to strike etc.

Table 1: Tibet's Unmanned Aircraft Operation—Total Flight Forecast

Service Type	2025		2030		2035	
	Flight Volume Hours	Fleet Size Quantity	Flight Volume Hours	Fleet Size Quantity	Flight Volume Hours	Fleet Size Quantity
Drone Logistics	1100	3	4000	8	9000	18
Agriculture	1400	2	7000	9	30000	38
Industrial	500	1	2000	4	4000	8
Total	3000	6	13000	21	43000	64

Source: Tibet Autonomous Region General Aviation Development Plan, 2021-2035.[14]

Indigenous UVs Industry. The Russo-Ukrainian war showed that the world's second largest defence exporter had to import UAVs from Iran and others while Ukraine relied on multiple countries. China is clear that a comprehensive indigenous UV industry is the need of the modern intelligentised battle-space. Apropos, Chinese military industry representatives like Huang Bin are recommending to step up the Chinese development and improvement of land combat equipment particularly UVs suited to different ways of fighting. They want to optimise on their low production costs but simultaneously pursue best technology development through talent acquisition and original innovation. The Chinese UAV military industry claims four advantages over the American UAV industry as elucidated below.[15]

- **CMF**. China has a small core and large cooperation system, which communicates smoothly with private enterprises, thereby reducing "stuck necks" and development risks. Through focussed CMF, PLA's scientific research units and universities have established strong research capabilities at the core of the private industrial chain.
- **Low Cost**. A comprehensive dual-purpose industrial production chain and low labour costs has kept the UVs production costs extremely low. A Wing Loong MALE costs nearly one million dollars as against a Reaper costing thirty million.

- **Diversified Industry**. While American UAV industry is mainly military oriented that too large size drones, Chinese UV industry is dual-purpose and diversified from large scale to smallest scale of quadcopters and micro drones. The early adaptation of Electric Vehicles, UAV based logistics service companies and driverless taxis and buses has ensured that the Chinese populace at large accepts the UV revolution.
- **Foreign and Domestic Demands**. The export and indigenous demands of Chinese drones and UVs has been expanding significantly since last decade. The non-ratification of MTCR has eased Chinese export. As per Stockholm International Peace Research Institute, China has exported 282 UCAVs to 17 countries in the last decade.

Future Technology Upgrades. Post analysis of American'2005-2030 UAV Development Roadmap", Chinese military UAV expertsare looking to upgrade the following key UAV related technologies as per their "Key Technology of UAV System" published by Aviation Industry Press and Military UAV Industry Report of June 2023:[16]

- **Aerodynamic Layout of Aircraft Body**. Keeping the manoeuvrability and speed in mind, the key aerodynamic layouts considered were normal, canard, and tailless. However, Chinese claim new innovations in aerodynamic layout like double tail, etc. as explained in Table below and are now aiming to lead the trend.

Table 2: Type of Aerodynamic Layouts and Latest Chinese UAVs / UCAVs

Layout	UAVs / UCAVs	Advantages	Disadvantages
Normal (Large Aspect ratio & small sweep angle)	WL-1 & WL-2	Long endurance	Low speed
Canard	CH-3	Improved lift-to-drag ratio & save engine thrust	Requires advanced flight control system
Tailless	WZ-8, GJ-11	High speed	Poor stability & low speed manoeuvrability

Trapezoidal wing (Large Aspect Ratio)	CH-4	Better stealth	
Double Vertical Tail	TB-001 / Scorpion	Large load, long range & strong stability	
"Φ" type connecting wing	WZ-7	Large aspect ratio, better structural strength & stability, reduced overall weight & flight resistance	

Source: Chinese 2023 Military UAV Industry In-Depth Report.[17]

- **Power Systems**. The turboprop and turbofan engines have been found to support the flight of medium and high altitudes and long endurance (MALE/HALE) UAVs with better fuel consumption rate and propulsion efficiency. However, turbojet engines and turbo ramjet engines have been found better for high-altitude and high-speed drones but turbojet engines unfortunately have the lowest propulsion efficiency and thus the highest fuel consumption.
- **Flight Control and Inertial Navigation System (INS)**. In order to enhance the Intelligentisation and Informatisation levels of the UV systems, the Chinese Military UV industry is focussing on the interactive control of human-machine intelligence integration and fusion. While the US military plans to make the drones fully autonomous by 2034, Chinese intend to lead the world and achieve the same earlier. In the field of GNSS chips for INS, CPC wants its domestic GNSS board manufacturer Beijing Hezhong Strong Technology Co., Ltd to match up the performance of the American GNSS board manufacturer Trimble Navigation Company.
- **Data Transmission Subsystem**. In a congested electromagnetic (EM) environment, Chinese have learnt their lessons and thus want to achieve low intercept probability and anti-jamming performance while simultaneously ensuring high spectral efficiency, communication security and reliability in tactical edge networks. They want to exploit latest anti-jamming communication technologies like direct spread, frequency, and time hopping to evade enemy interception by hiding signal features in the time or frequency domains.

- **ISR Payloads**. Having realised the limitations of electro-optical (EO) payloads in bad weather conditions, PLA intends to develop high resolution synthetic aperture radar (SAR) payloads to ensure 'Zero-casualty ISR flights' without the need to lower flight altitudes during ISR missions. They claim that CH-4 UAVs have achieved SAR detection range of 50 km and a four-in-one EO platform range with a detection range of 15 km.

Logistics. The Eastern Ladakh standoff since 2020 was an eye opener for WTC particularly to sustain enhanced WTC deployments over the entire Indian borders with Tibet and Xinjiang. PLA's efforts are summarised by a PLA Daily article on Chinese Ministry of National Defence website. It states 'Since 2020, the relevant departments of the Logistics Support Department of the Central Military Commission (CMC) have focused on the urgent needs of front-line support, and have worked with the Army Logistics Department to study and solve the problem of material supply for plateau border troops, and make every effort to get through the "last mile" of material supply at border posts. After in-depth research and demonstration, they decided to set up a UAV transportation and delivery support team, set up UAV take-off and landing fields in the mountains, and coordinated with relevant departments to open the flight airspace and open multiple UAV air transportation and delivery supply lines.'[18]

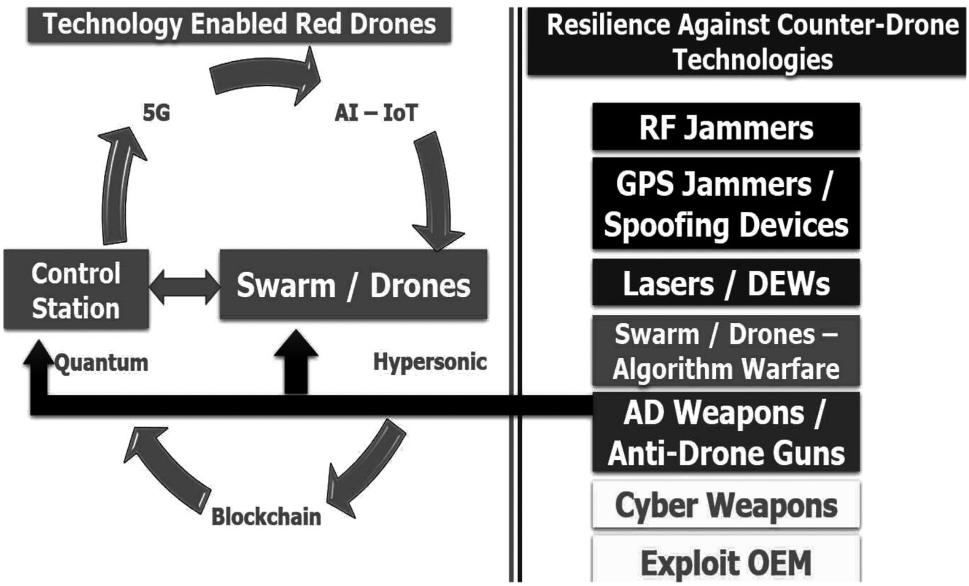
Drones Infested Environment. The Armenian and Ukrainian wars have clearly showed that the modern battle-space will be infested with drones. As per TJ Holland a US soldier, the battle for Bakhmut witnessed up to 50 drones in air at any one time with nearly 86% of all Ukrainian targeting data derived from drones. While the drones are collecting data amounting to nearly petabytes per hour, the congested EM bandwidths and constant EW have ensured that drones can transmit only few kilobytes of vital information. The time difference between Russian artillery units' strikes between those with and without drones was nearly 25 minutes with the ones having integral drones just taking two to three minutes. As per Shashank Joshi's data analysis, Ukraine is nearly losing 10,000 drones per month with the average life expectancy varying from just three flights for a simple quadcopter to about six for a fixed-wing drone.[19]

Counter-Drone Measures. The Russo-Ukraine War has highlighted the inadequacy of current AD systems and tactics to completely protect against UAVs but also the importance of both kinetic and non-kinetic methods in targeting adversarial drones. The PLA has realised the primacy of EW in denying communication links between the UVs and ground control stations. While the American Gulf War of 1991 highlighted the importance of gaining Air Supremacy, the Russo-Ukraine and Armenia-Azerbaijan conflicts have adequately proved that EW supremacy is an essential requirement before Suppression of enemy AD (SEAD) which is further the pre-requisite for establishing favourable air situation in the intended theatre of operations. PLA is thus testing and validating all new anti-drone technologies and inducting the same at appropriate levels. PLA is moving towards closely integrating all AD, anti-drone, and Ballistic missile defence (BMD) assets in an integrated air-missile defence grid. PLA's simultaneous advancements of drone, swarm, and anti-drone technologies is explained by an infographic at Figure 5.

The key Chinese lessons culled out till now have proved to the PLAthat Tactics no more determines Technology but it is Technology and its fast-paced advancements that are determining new tactics and doctrines. Hence, PLA's evolution of tactics has commenced for employment of complete assortment of drones–large, medium, small, suicide, stealth, swarms, and loitering munitions etc. Having realised that drones are the biggest enemy of tanks, they have focussed strongly on anti-drone equipping of their Heavy and Medium CABs. They have realised that in a Medium and Light CAB, their infantry tactics must undergo change wherein the infantry needs protection during move and combat. The Information Warfare and propaganda departments need transformation particularly on social media where it is important to share in near real time the drones' videos and images of successful precise strikes.[20] PLA's continuing 'Below the

Neck Reforms' are thus focussing on pragmatic UVs and combined arms integration.

Figure 5: PLA's Technological Transformation for Drones / Swarm Warfare

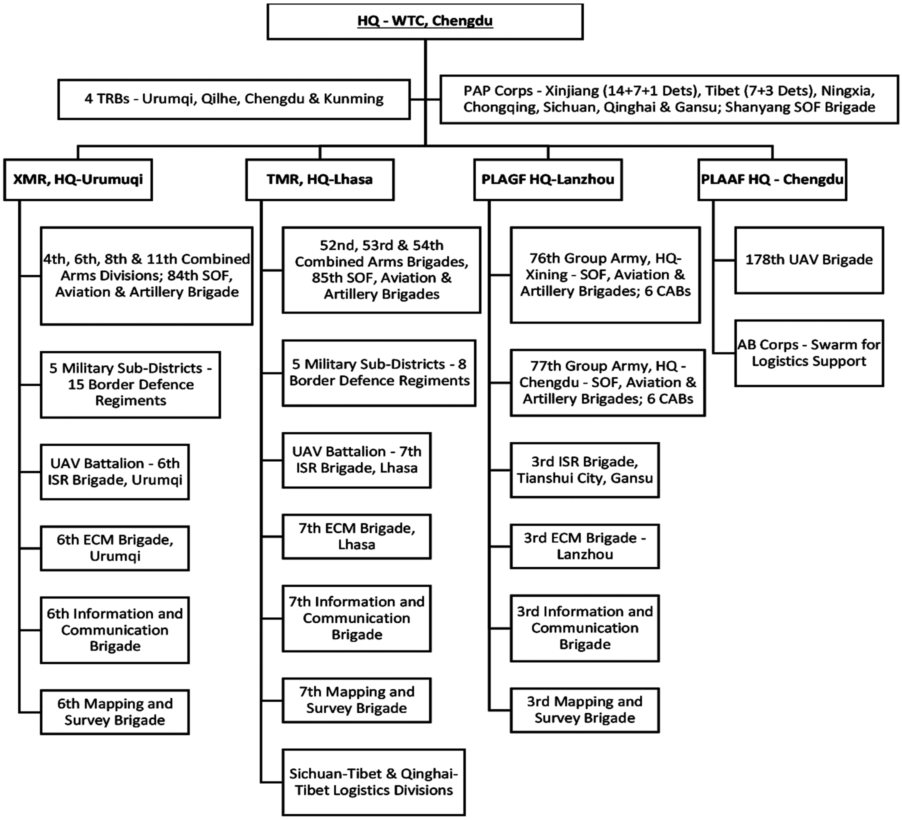


Source: Author's Book 'PLA's Tactical Transformation'.

PART 2: INDUCTION OF DRONES IN WTC

The PLA's Military Districts / Regions controlling the Xinjiang and Tibet provinces– Xinjiang Military Region (XMD / XMR) and Tibet Military Region (TMD / TMR) must cope with the most challenging terrain for employment of drones i.e., the high-altitude areas (HAA) of Himalayas and Kunlun Mountains, temperature variance in the Tibetan plateau and the Taklaman Desert etc. PLA has still gone ahead with a massive pace of field and combat trials for induction of the successful variants in the WTC. The key drone organisations in the WTC are explained by the infographic below.

Figure 6: WTC's Key Organisational Structures with Drones



Source: Author's Books 'PLA's Tactical Transformation', 'Trajectory of Red Army's Unmanned Warfare' and further research.[21]

The organisational structure for handling of loitering munitions, swarms and UGCVs is still not clear as their induction information remains opaque. The WTC propaganda handles do keep uploading various photos and videos indicating trials at many high-altitude locations. The known details of WTC's units and formations equipped with UVs at various levels are expounded below and summarised at Table 3.[22]

- **Border Defence Regiments (BDRs)**. BDRs form the first layer of PLA's response mechanism. While very less is known in OSINT about BDR organisations, they have held drones for border patrols since 2017. PLA's troops along Indian border hold CH-802 (1kg payload, 2.5 hours, 10-35 km) and CH-902 (0.6 kg payload, 1 hour, 15 km) small drones. TMR's BDRs were the first ones to show propaganda videos of forward delivery of food and logistic support items at PLA's Meto post opposite own Arunachal Pradesh. The PLA's propaganda video of February 2022 and related articles claimed establishment of a UAV aerial delivery channel making the UAV based intelligent transportation and delivery of materials a reality particularly when roads are blocked due to adverse weather conditions. Thus, BDRs' forward HAA posts claim to exploit mini drones as 'air mules and horses' for ensuring remotest point-to-point transportation delivery. While Meto was a starting point in TMR in 2022, it was supposed to spread to other BDR locations soon.

Figure 7: Border Defence Unit's Drone Detachment (ex 355th BDR) and Mengshi Vehicle with dedicated optoelectronics surveillance mast to launch DJI drones

Source: Huaxia.com and Twitter Handle Some PLAOSINT.[23]

- **Combined Arms Battalion (CABn)**. At the lowest tactical level, the CABn's Reconnaissance Platoons are equipped with quadcopters. The scouts have been provided with handheld Quadcopters like DJI Mavic, Harwar H16-V12, and CH-902 etc.

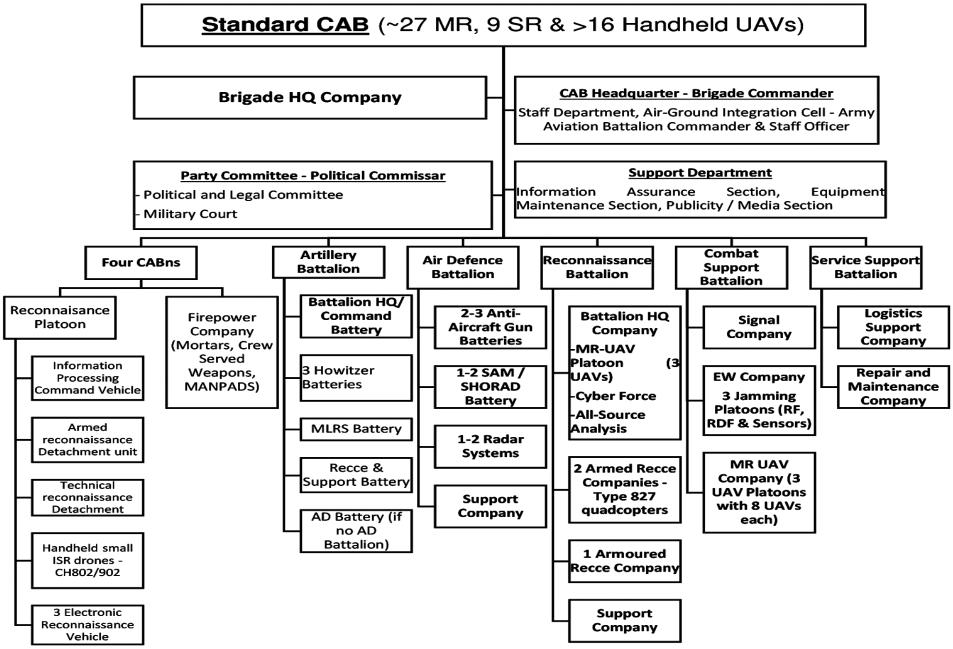
- **Combined Arms Brigade (CAB)**. Apart from CABns, UAVs have been inducted in to CAB with its Reconnaissance, Artillery and Combat Support Battalions. The Reconnaissance Battalions most likely have One UAV Platoon with 3 Medium Range UAVs each, and one Armoured Recce Company most likely authorised 9 Vehicle Launched Short Range UAVs. The CAB's integral 122mm howitzer Artillery Battalion's Command, Reconnaissance and Support Company most probably hold JWP-02 UAVs or BZK008s. The Combat Support Battalions additionally have one Medium Range UAV Company, with total 24 UAVs, comprising 3 MR-UAV Platoons with total 8 UAVs each. One Chinese article aptly sums up their drones' induction in TMR as cited below:

> "Equipped with the PLA's anti-Indian border troops, the reconnaissance unit of the CAB of the TMR no longer manually blasts the enemy's roadblocks when attacking, but uses a Type-827 quadcopter with only a few kilograms to fly at low altitude over the obstacles and throw explosives to blow up the roadblocks. This quadcopter can be carried by a single soldier, which can perform reconnaissance and surveillance tasks, and can also carry miniature bombs to perform attack tasks."

An appreciated drones' organisational structure in a CAB is elucidated below at Figure 8. It shoes appreciated drones' holders, users, and anti-drone equipment.

- **XMR's Combined Arms Divisions (CAD)**. The newly reformed 4^{th}, 6^{th}, 8^{th}, and 11^{th} CADs of XMR have one Artillery Regiment each and one Support and Logistics Regiment each. The 12 Combined Arms Regiments (CARs) have 12Reconnaissance and 12 Artillery Battalions which will be nearly of the same composition as that in standard CABs. Appreciated drone structure in XMR's units and formations is attempted at Figure 9.

Figure 8: Drones & Anti-Drone Equipment in CAB

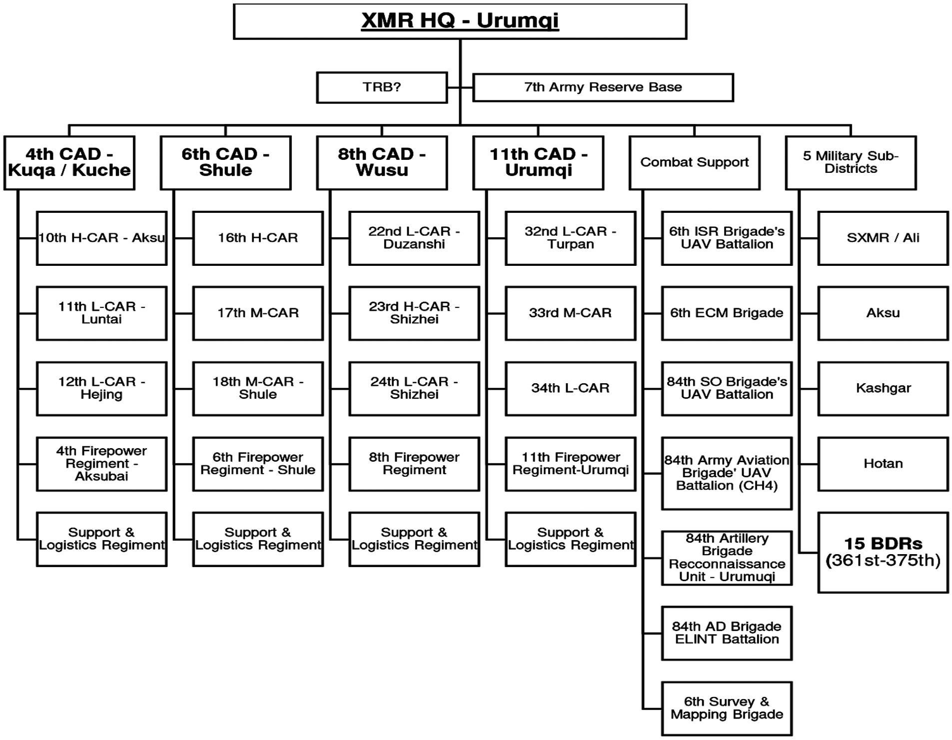


Source: Author's Book 'PLA's Tactical Transformation' and further research.[24]

- **Group Armies (GAs)**. The 76th, 77th, 84th (XMR) and 85th (TMR)GAs' Artillery Brigades' Reconnaissance Units have UAVs with longer endurance range up to 300 km, like the SX500, to support long range-MLRS like PHL191 with near real time provision of targeting information. Similarly, the four GA's SOF, Service Support, and Army Aviation Brigades have one UAV Battalion each most probably while the AD Brigade's ELINT Battalion also have UAVs. The four PLAGF Aviation Brigades in WTC generally have CH4 UAVs which are in key heliports or alongside the PLAAF Airfields in Tibet and Xinjiang mainly.
- **Militia**. The new type Militia units, mainly in Tibet, also have UAVs.
- **WTC**. The WTC has three ISR Brigades—one each with WTC PLAGF HQ (3rd), XMR (6th) and TMR (7th). These ISR Brigades are all equipped with minimum one UAV unit each. The WTC PLAAF HQ has 178th UAV

Brigade. Furthermore, the three ECM and Mapping and Survey Brigades also have UAVs.

Figure 9: XMR's Unique Organisational Structures with Drones



Source: Author's Book 'PLA's Tactical Transformation' and further research.[25]

Table 3: PLA's Drone Platforms at Various Levels in PLA's WTC

Level	Unit / Formation	Type of Drone	Task	Remarks
23 BDRs	Border Defence Battalions (including JN1101 Anti-drone system)	Quadcopters/ micro-drones; CH-902& CH-802 small drones	ISR, patrol, Targeting, BDA, Logistics	First layer of PLA's response in WTC
CABns (≥96 in WTC)	CABn – Recce Platoon (96)	DJI Mavic, Harwar H16-V12, and CH-902, CH-802	Tactical ISR and light air-support.	Tracked Vehicle Based / Hand-launched

CABs / CARs (15 CABs, 12 CARs)	i) Recce Battalion – MR UAV Platoons (15+?), 9 Vehicle Launched SR-UAVs per Battalion	**Swarm?**, Type-827 Quadcopters Four types of drones BZK008s & JWP02s / ASN 206	ISR and artillery fire direction	Unit holding swarm and induction both need confirmation Drones-Up to 100 km range
	ii) Artillery Battalion (27) iii) Combat Support Battalion – MR UAV Company (15+?)			
CADs (4)	Firepower + Support & Logistics Regiments – MR UAV Company (4+4)			
XMR (84th GA), TMR (85th GA), 76th & 77th Group Army	SOF Brigade UAV Battalion (4)			
	Artillery Brigades / Regiments – UAV Company (4+4)	SX500, ASN206, ASN209[26]	targeting information for LR-MLRS	Up to 300km
	Army Aviation Brigades (4)	CH4 UCAV, AV500W / Blowfish A2[27] Unmanned Helicopters		
	Service Support Brigades (4)	UAVs		
	AD Brigade ELINT Battalions (4)	ASN 206 ECM drones		
Western Theatre Command	ISR Brigade – UAV Battalion (3)			
	ECM Brigades (3)	ASN 206 Series	EW / ECM Payload	
	Three Mapping & Survey Brigades		Mapping	
	PLAAF- 3rd UAV & 178th Brigades	CH5, BZK-005, WL2		Up to 6 UAV Battalions
	Xining based Logistics Support Forces			

Militia	UAV Dadui	TB-001 / Scorpion drones	Forest Monitoring Fire Control	
Fire Fighting Department	Kailan Training Base, Xinjiang			
Forest Department	Kalamali Wildlife Nature Reserve, Xinjiang			

Source: Author's Book 'PLA's Tactical Transformation' and further research.[28]

Challenges. While the quantum of drones being inducted is phenomenal, it surely will be presenting a series of challenges to WTC. The key anticipated challenges would be the EM spectrum management to provide so many data links within restricted available frequency slot particularly in an EM congested and contested environment; availability of air space at various altitudes to fly so many drones; and off course ensuring Identification Friend or Foe (IFF) between the drones and the anti-drone devices both in kinetic and non-kinetic domain.

While 179th Light-CAB of 71st Group Army conducted an Urban Warfare Exercise involving UGVs in a multi-domain UVs mode, WTC is yet to see such a detailed proliferation. The exercise propaganda videos featured troops-unmanned equipment integrated zone contests with nearly 100 simulations for detailed coordination between each individual soldier and large weapons. The application of UGVs in HAA is a challenging task but would surely need to be monitored closely.

However, it must be remembered that Chinese are not 10 feet tall. Repeated failures of Chinese UAVs in West Asia and Ukraine are not only a matter of concern for PLA but also for their iron brothers Pakistan Army. While Pakistan was forced to opt for Chinese CH-4 and WL-2 UAVs initially despite repeated failures in field trials, the Pakistani Army is now slowly shifting towards Turkish UAVs and UCAVs with a much better success rate.

PART 3: INFRASTRUCTURE DEVELOPMENT IN WTC

In order to support the employment of large quantum of drones inducted, it is axiomatic that PLA had to build the requisite infrastructure, mainly high-altitude area based, in WTC. The WTC infrastructure developed has been divided into the two sub-theatre level Military Regions/Districts (MC/MD) i.e., the XMR and TMR.

Table 4: Drones Infrastructure Airports / Heliports in XMR

Location	Year	Altitude (Rw Length)	Development/ Upgradation	Likely WTC Formation	UAVs Seen / Possible
Development / Upgradation Since 2017					
Aksu Onsu	2018-2020	1169		2nd Battalion/ 178th UAV Brigade	**CH-5**
Atlay	2017-2019	764			Possible
Hami	2020-Current	830		PLAAF's Xi'an Flight Academy 2nd Training Brigade	Possibly PLARF
Hotan	2020-Current	1420 (4000)	2nd runway, UAV Hangars		CH4, CH5, 3-5 WZ-8 (Hypersonic?)
Kashgar	2017-Current	1374 (3200)	12 Hardened Shelters	Kashgar Fendui/Det	WL2 / CH5
Malan Uxxaktal	2021-Current	1105		PLAAF 1st & 2nd Battalions/ 178th UAV Brigade	All types
Ngari-Gunsa	2020-Current	4270 (4500)	12 Shelters, 2nd Runway	UAV Test Base	2-3 WZ-7&WL2, CH4
Tumxuk T'cheng	2018-2021	1089			

Turpan Jiaohe	2020-Current	265			
Urumqi South	2019-2021		Shelters	PLAAF Air Brigade	Possible
New Constructions Since 2017 (Possible UAV Deployment on Completion)					
Gerze Heliport	2020-Current	4441			
Ngari Bura ng / Pulan	2021-Current	4288 (5000)			Possible
Rutog/ Domar Heliport	2020-Current	4549	18-20 shelters	PLAGF 84th Army Aviation Brigade	
Tashkorgan	2020-2022	3255 (3900)			Possible
Tashkorgan Heliport	2020-2020	3150			
Xaidulla Heliport	2017-2018	3673			
Yutian Wanfang	2019-2020	1442			
Zhaosu	2019-2021	1743			
Unchanged					
Korla	-	925		PLAAF 111th Air Brigade	Possible
Ngari Heliport	2017	4290		PLAGF 84th Army Aviation Brigade	
Shache / Yarkant		1295			Possible
Urumqi Changji		740		PLAAF 109th Air Brigade	Possible

Source: Author's Research.[29]

Table 5: Drones Infrastructure Airports/Heliports in TMR

Location	**Year**	**Altitude (Rw Length)**	**Development /Upgradation**	**Likely WTC Formation**	**UAVs Seen /** Possible
Development Seen Since 2017					
Shigatse Hoping	2017-2023	3807	UAV Shelters, Underground Facility	PLAAF UAV Det /Fendui	6-8 CH4, WZ-7/GJ2, TB001
Lhasa Gonggar	2017-Current	3575	24 Shelters, 2nd Runway, SAM site	PLAAF 3rd Battalion/178th UAV Brigade	BZK-005, WL2
Lhasa Heliports – Lhasa, Sangoa, Thio & Dechen	2020-2021	3630	Sangoa(2 km x 1.8 km) – 48 hangars, 14 helipads	PLAGF 85th Army Aviation Brigade	Lhasa-CH4
Qamdo Bangda / Chamdo Pangta	2020-Current	4345 (5500)	New Runway, Inflatable temporary hangars	PLAGF 77th Army Aviation Brigade	WZ-7, CH4
Nyingchi Mainling	2017-Current	2950	SAM site, new runway & taxiway	Civil Aviation Tibet Bureau Drone Training Base	WZ-7
Nyingchi Heliport	2020-2020	2957		PLAGF 77th Army Aviation Brigade	
New Constructions Since 2017 (Possible UAV Deployment on Completion)					
Tingri	2019-Current	4316.5 (4500)			Possible
Damxung / Donshoon	2020-2023	4302			Possible

Kangmar/ Kalashahr Heliport	2020-Current	4437			Possible
Longzi/ Serche / Lhunze	2019-Current	3944 (4500)	SAM site		Possible
Nagqu / Seni Heliport	2020-Current	4492	18 hangars	PLAGF 85th Army Aviation Brigade	
Nyima Heliport	2020-Current	4576	18 hangars		
Planned Infrastructure Upgrade / Yet to be Completed (Possible UAV Sites Later)					
Gyantse		(765x35)		PLAGF 54th Heavy CAB	20 Unknown UAVs
Tsona / Cuona		4366			Possible
Yadong / Yatung					Possible
Meto / Medog		(2500)	Site survey undertaken		AR500 / X6L-15 UAV

Source: Author's Research.[30]

UAV AIRPORTS

The Chinese also intend to slowly graduate from the current concept of hybrid manned-unmanned airports to purely UAV Airports. A Chinese site Sohu.com defines UAV airport, or UAV hangar or UAV "nest" as 'an unmanned application carrier for industry scenarios, with out-of-the-box, autonomous controllable, stable, and reliable, data localization, software, and hardware. With the characteristics of integration, high environmental adaptability, and multi-weather adaptability, the UAV can be directly deployed to the job site to solve the problem of manually carrying the UAV to commute, which can not only enhance the emergency operation ability of the UAV, but also improve the operation efficiency.' While a clear plan could not be confirmed for WTC, various Chinese documents do hint towards establishment of UAV Airports.[31]

Functions. The broad appreciated functions of UAV airports, from Chinese perspective, are listed below:[32]

- Provide protection against harsh weather conditions, theft, and wild animals.
- Power supply by charging or replacing the battery.
- Automation of take-off, landing, alignment, storage, payload loading and unloading.
- Centimetre-level precise positioning and navigation.
- Hangar's internal temperature and humidity adjustment, external detection, and monitoring.

Composition. The UAV airportmainly comprises of three parts:[33]

- **Hangar body**. It comprises a protective shell, an automatic opening and closing door, a UAV lifting platform, and a UAV fixed mechanical structure.
- **Module inside the Warehouse**. This module further consists of the
  - ☞ **Organic Airport Control Module**. This is planned to be the control centre of each component of the hangar body responsible for the safe take-off and recovery of drones.
  - ☞ **Battery Charging and Swapping System Module**. Charging modules do not need to replace batteries but charge them while battery swapping modules replace batteries straightaway.
  - ☞ **Environment Monitoring and Adjustment Module**. This module is managing suitable temperature and humidity in the hangar.
  - ☞ **Ground Station Module**. It is responsible for the data transmission between the remote command terminal and the drone, the command terminal and the automatic airport, the uplink and downlink data and image transmission between the automatic airport and the drone Module.
- **Equipment outside the Warehouse**. It mainly includes environmental monitoring equipment and photoelectric monitoring equipment.

Types. The Chinese scholars currently divide the UAV airports into three types - Fixed and vehicle-mounted; Swappable and rechargeable;and lastly Multi-rotor, compound wing and vertical fixed wing types.[34]

UAV Airport Application Scenarios. The UAV airports, from Chinese perspective, are planned to be exploited for unmanned inspection of power grids, wind turbines, and communication base stations etc located in remote areas; conduct of UAV Patrols; Remote sensing mapping; Emergency operations and response; and Logistics and distribution.[35]

PART 4: UVS' EMPLOYMENT FOR MDPW AND MDIJO

> "In 2019, the AV500W reconnaissance and strike integrated unmanned helicopter also appeared on the Tibetan plateau. This unmanned helicopter weighs 450 kilograms and has a ceiling of 6,700 meters. It can carry 4 small laser-guided air-to-surface missiles to accurately strike enemy personnel and light vehicles. With its excellent plateau performance and rapid response deployment capability, it is easier to use than the Z-10-armed helicopter……. Additionally, Blowfish A2 unmanned helicopter can drop precision-guided mortar shells which even if thrown away, can serve as a reference for the large-calibre mortars belonging to the CAB to attack the target…. the unmanned helicopter just hovering over their head, dropping a 60mm tear gas bomb from time to time or using a loudspeaker for 24-hourmental torture, is far less risky.... In the event of an armed conflict, the WL-2[36] HALE UCAV can be dispatched to attack."
>
> Propaganda by Chinese Article on 163.com – 14 December 2022[37]

The PLA's employment of UVs for MDPW and MDIJO, as observed from their propaganda videos or by reading and analysing their conceptual articles, will broadly be for Intelligence Surveillance and Reconnaissance (ISR) and Battlefield Damage Assessment (BDA) in support for combat operations; Targeting as conductors of a symphony of fire and destruction–whether stand-alone, swarm or manned-unmanned teaming (MUMT) including loyal wingman tasks; Combat Support Operations like Communication relay and jamming; direction of artillery fire, drone rescue operations and logistics. These key tasks are discussed in detail below with special focus on WTC.

Figure 10: UVs' Organisation Structures and Types of Tasks in WTC

Level / Tasks	ISR & BDA	Targeting	Combat Support Operations	Logistics
Tactical	CABn's UAVs, CAB's UAV Company	AV500W	CH-802, 902	BDR Logistic Delivery Drones
Operational	UAVs ex Artillery and Army Aviation Brigade	CH4 UCAVs	UAVs ex 3rd, 6th & 7th ECM & ICB Brigades	MR's division level depots
Strategic	178th ISR Brigade	PLAAF WZ-7 UCAVs	SSF ECM UAVs	Logistics Support Brigade

Source: Author's Research, Analysis and Appreciation.

Execution Methods—UV Operations. PLA's intentions are clear to employ UVs in all types of combat tasks from lowest tactical to highest strategic echelons. The UVs can execute the multi-disciplinary tasks by creating a Swarm[38] (fengqunshizuozhan, 蜂群式作战) as a multi-domain or single-domain cluster of UVs; by employing Marsupial drone concept or employing Mother-ship Swarm Operations (mujianfengqunjiqunzuazhan; 母舰蜂群集群作战); as Intrusive Lone Wolf (qinrushi du lang zuozhan; 侵入式独狼作战) as a single unmanned UV or loitering munition completing the kill chain cycle on its own; or a hybrid team of "Hunter" and "Hound" or Manned-Unmanned Cooperative Combat MUMT; for anti-stealth, anti-superior, anti-swarm operations; as part of Unmanned Space Operations; execute mine-sweeping operations; and even for weather modification. A recent Guancha.com article has claimed that PLA's National University of Defence Technology has developed an intelligent swarm where in algorithm-based control enables the swarm to maintain combat effectiveness automatically and dynamically by re-forming and reconfiguring whenever some parts are lost to enemy fire.[39]

Figure 11: Tengden TB-001A with Cloud Seeding Payload in Tibet

Source: '78' Blogger at Sino-Defence Forum.[40]

Chinese media is claiming that the Chinese Twin-Tailed Scorpion or Tengden TB001 UAV has achieved the world's first mother-child UAV concept. The concept basically entails that while the mother aircraft Scorpion UAV can perform its standard mission of reconnaissance and strike, the children i.e., two small FH96V UAVs can also be mounted on it. Since the three-engine version Scorpion, characteristics as per Table below, was not found to be the most suitable choice based on lessons of Russo-Ukraine War, the Sichuan Tengdun Technology Company developed the 2019 model into a mother-child where the mother – Scorpion model shall carry two children smaller FH-96V UCAVs with a MTOW of 100 kg and payload of 15 kg.[41]

Table 6: Development of Sichuan Tengden Technology Company's Scorpion / TB001 UAV Models

Parameters / Version	Basic - 2017	Three Engine Version -2019	Four-Shot Scorpion - 2023
MTOW (Tons)	2.8	3.25	4.35 (Space 5 cubic m)
Payload (Ton)	1	1.5	1.5 / Two FH-96V UAVs
Maximum Range (km)	6000	7200	Mother 7200, Children 400
Maximum Airborne Time (hours)	35	35	Mother – 35, Children – 8
Maximum Ceiling (metres)	8000	9500	
Cruise Speed (km/h)	220	300	

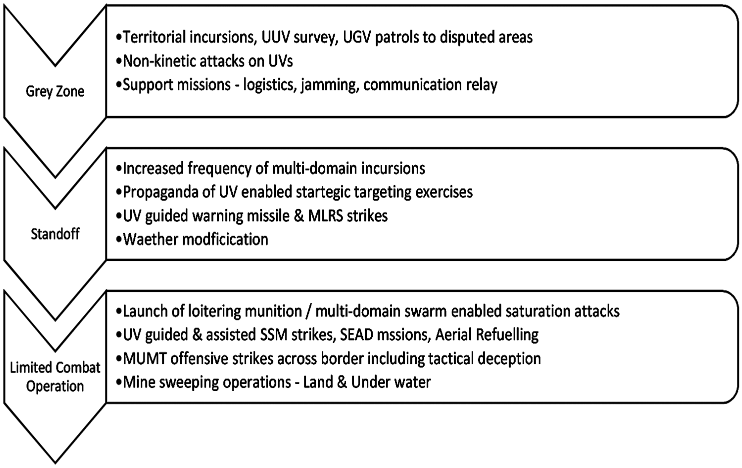
Source: Toutiao.com[42]

Such MUMTs are being formed by PLAAF and PLAGF alike. While the PLAAF's combat package may use a stealth UAV as a loyal wingman or just independently for ISR / BDA, analysis of PLAGF's training activities and videos continuously highlights the aspect of increasingly close coordination between aviation helicopters and CH4 UAVs for joint offensive missions and MLRS like PCL-191 / PHL-16 and PHL-03 and ASN series and other UAVs for ISR, BDA and dynamic targeting. The extensive employment of UVs by PLA's tactical echelons although will be challenging but will surely reduce the similar requirements at higher levels.

Future. PLA has missed its Mechanisation timeline of 2020 many times already. It has still not achieved the desired degree of Informatisation and basic levels of Intelligentisation. As PLA has not been able to catch up with US and Russia in the field of tanks, the Russo-Ukraine war lessons are making China focus more on drones, swarms and RCVs. While a lot has been discussed and written about drones and swarms, Chinese are moving fast in the domain of UGVs, UGCVs and UUVs achieving greater depths, higher altitudes, better quality and in greater number of HAA demonstrations and ocean-base surveys in Indian Ocean Region. Chinese are surely aware of the reality that Western Lead in Mechanisation can only be covered by RCVisation. Apropos, Chinese drone firms and researchers at PLA's Academy of Military Sciences are working to develop intelligent control system capable of directing multiple UAVs, UGVs, and loitering munitions. The provision of smart helmets, smart foregrips, and smart gloves to infantry soldiers, under Intelligentisation plan, are being shown in multiple propaganda videos.[43]

The study of Chinese Science of Military Strategy 2020 and analysis of its multiple standoff activities in South China Sea and East China Sea, Taiwan Strait crisis of August 2022 and April 2023 reveal a peculiar Chinese style of escalation along the Strategic Deterrence ladder. An appreciated futuristic PLA's employment of UVs is attempted below:

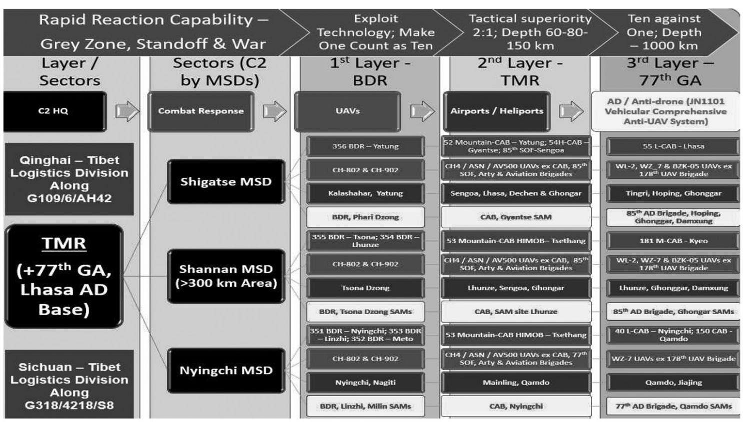
Figure 12: PLA's Employment of UVs for Strategic Deterrence



Source: Author's Research and Appreciation.

As part of WTC's layered border defence strategy ("Less in the Front, More in the Rear") adopted post Eastern Ladakh standoff of 2020, PLA now intends to use UVs at each layer to enhance the response. An example of WTC's layers under TMR, is lustrated below:

Figure 13: TMR's Employment of UAVs for Layered Border Defence



Source: Author's Research.[44]

PART 5: IMPLICATIONS

> In today's crisis-ridden world, workers in China's military industry—boasting a glorious 91-year tradition of self-reliance, hard work, a can-do attitude, and a pioneering spirit—will stand shoulder to shoulder with the mighty Chinese PLA and jointly build and defend a great wall of steel that safeguards national sovereignty, security, territorial integrity, the happiness of the people, and national rejuvenation.
>
> – Huang Bin[45]

While the PLA is surely short of battle experience with only few odd serving generals with any prior experience of Vietnam War, PLA's drones have been battle-tested in numerous recent and ongoing conflicts including its own grey-zone situations both maritime and continental. Hence, the quality of their UVs is likely to improve with every battle their defence and civilian companies test them in difficult conditions. With the increasing and largest UVs production base and correspondingly extremely high market share, Chinese military unmanned industry should be able to withstand the drones' attrition battle indigenously much better than any other country. The civilian and military manufacturing advantages gradually are also likely to result in doctrinal evolution and organisational structure reforms.

Battle of Algorithms. The three pillars of Intelligentisation are data, computing power, and algorithms. India's software talent is recognised worldwide and is the most suited country to develop the strongest and most resilient algorithms. Hence, as PLA transforms its combat preparations from fighting a system-vs-system battle to algorithms battle, Indian defence forces need to be fore-warned and proactively prepared.

Comprehensive Integration. While the Russo-Ukrainian war is showing the best of the UAV system single-platforms executing closed kill-chain operations, there is a gradual transformation towards intelligent multi-domain UV clusters requiring precise manned-unmanned coordination and collaborative UAV swarm operations. However, the machine-machine integration is still a challenge particularly the concept of cross-disciplinary cueing amongst UVs for corroboration and tasking.

Space Domain. Chinese National Rejuvenation Dream is critically reliant on transforming PLA into a world-class military by 2049 which is further dependent on Space Super Power Dream and UVs Powerhouse Dream. While Chinese Super-Power dream requires flooding of outer space with UVs and satellites, the further development of drones need to be assisted by Space Domain in multitude of application scenarios. The secured and farthest temporal reach can only be assisted by broadest bandwidth satellite communication, longest endurance can be stretched by solar chargers or space-based laser chargers, precise navigation and guidance assured by resilient and global spatial coverage of space-based PNT constellations, and all-weather ISR / targeting data backup by space-based remote-sensing constellations with least possible temporal revisits. Thus, PLA is strengthening its space infrastructure to fight a modern UVs battle.

Congested Near-Space. As the low-earth orbital (LEO) slots get occupied, advanced space powers like China are looking for establishing very low-earth orbit (VLEO) satellite constellations. Simultaneously, the military drone industry is intending to increase the altitude of drone flights to enhance survivability, exploit solar power for longer endurance and expand swath thereby spatial ground coverage. This multi-directional pull will lead to congestion of less explored near-space domain, extending from 30 to 100 kilometres from sea level, just above the air domain but below the outer space domain.

Recycled or Converted Drones' Fleet. PLA is also modifying obsolete aircrafts as UVs like J-6, J-7 and J8 aircrafts.[46] WTC's few propaganda photos also showed PLA attempting the same with T59 tanks. They are likely to employ a fleet of modified drones.

Future Force Composition. Chinese analysis of US military's UVs development predictions make them opine that UAVs, UUVS, RCVs and UGVs will become the mainstay equipment for the future intelligentised battlefield. Furthermore, quoting US Army Research Laboratory, they predict that before 2035, human-machine coordinated operations would have progressed from human-in-loop to human-on-loop autonomous operations; and to human-out-of-loop or fully autonomous operations before 2050.[47] Thus, PLA's military policy reforms and training guidelinesare catering for force compositions, skills development, talent harnessing and domain super specialisation.

Logistics. The increasing employment of UVs by PLA's WTC for logistics, even if propaganda, is going to slowly facilitate logistics in difficult high-altitude areas as the technology and machines evolve to exploit them in adverse terrain and weather.

Figure 14: PLA's Employment of UGV for Ammunition Loading

Source: Twitter Handle @KushigumoAkane and Przemyslaw Juraszek.[48]

PLA's employment of wide array of both combat and support UVs will surely require a well-integrated, responsive, interoperable, and enmeshed AD grid which can tackle aerial threats from all types of unmanned assets – missiles both cruise and ballistic, small, medium, and large sized drones, etc.

The grid will not only require to timely detect incursions but also ensure a suitable response both in the kinetic and non-kinetic domain.

CONCLUSION

PLA scholars define 'Unmanned Combat' as a concentrated manifestation of the integration and development of Mechanization, Informatisation and Intelligentisation. PLA is looking to move towards '**Tactical Autonomisation**' as they transform from the erstwhile mechanised warfare concept of 'Missile Overwatch' to 'Drone Over watch'. PLA appreciates that AI-enabled unmanned technology will gradually expand to other areas such as 'network-attack and defence, electronic countermeasures, multi-source perception, correlation verification, character tracking, public opinion analysis, and infrastructure management and control. Chinese military scholars are right when they opine that the biggest difference between intelligent weapons and other weapons is that as a weapon, it will continuously improve itself. As a next progressive step with the translation of accumulated actual combat and training experience into big data, stronger algorithms will integrate these advantages and responses to perform better in the war.

As the modern battle-space sees a progressive shift from mass waves of soldiers to hybrid waves of soldiers and UVs to finally mass waves of multi-domain UVs, the future of UVs warfare will depend on the quality of algorithms, positive indigenous production capacities and resultantly assured low costs of development. Indian defence forces need to cater for fighting a cross-domain mix of medium and large multi-disciplinary UVs while simultaneously enhancing resilience against air/ground/under-water-launched UCVs, swarm and consumable UVs, and other miniaturized and low-cost UVs. Most importantly, indigenous civil industry needs to be strengthened policy wise and infrastructure based to fight this intelligentised decoy and swarm warfare in an increasingly UVs infested, GPS denied, cognitively contested and EM congested environment. While low-cost UVs will flood the battlespace, the commanders will drown in data collected and presented. PLA is thus preparing for a new 'Autonomisation Era', evolving doctrinally to lead men and machines alike but with 'Loyalty to Party' first, suitably enabled by intelligent decision support algorithms, in a technologically led fast-paced battles digitally witnessed globally.

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38. As defined in author's book, a swarm, exhibiting bionic behaviour, is "an intelligently and precisely formed robust group of highly decentralized and autonomous intelligent unmanned vehicles technically driven by AI, networked information systems, self-organized and self-adaptive collaboration and cloud computing, in which unmanned platforms communicate in a centralized manner with each other to build a comprehensive perception of the environment, autonomously respond to changing conditions and perform multiple tasks simultaneously like multi-dimensional precise reconnaissance and multi-target strikes by achieving combat integrity through dynamic energy accumulation, precise energy release, and victory by quantity."
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MANNED-UNMANNED WARFARE IN MOUNTAINS: ASSESSING LATEST TRENDS

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Abstract

The Ukraine conflict has thrown up a number of challenges to ways of conducting war, as also thrown open windows to gain asymmetric leaps against formidable capabilities. This discussion draws some lessons especially in teaming manned and unmanned assets. This is examined in a mountain template with specific focus on helicopter-UAV teaming, a multi-domain context, and newer concepts in a fast-changing and adaptive character of war. Many recommendations are made along the discussion **and the short scenario depicted**.

INTRODUCTION

The Russo-Ukraine conflict has questioned many fondly-held western concepts and tactics of conducting military operations. While it has thrown up many questions on existing platforms on land, sea and air, airpower employment, or rather the lack of it as perceived, has generated the largest critique. For example, a vexing issue is the size and integration of vulnerable manned platforms and a growing expendable unmanned component, both combat and its support, in such intense and contested battlefields. This article explores the analyses from both sides of the battle-lines, and suggests some lessons for India especially against the Chinese Military (PLA) context across the mountainous Line of Actual Control (LAC) with emphasis on helicopter/UAV teaming.

In an environment of false narratives, lack of credible data and hyper-marketing strategies of the military-industrial complexes, it is important to see through the fog of technological promises, and grasp the nuances of the complex, uncertain and fast-changing ways of military campaigns. This is important so that large investments in capability-building are not laid waste tomorrow. **The issue of armed one-way drones** and manned-unmanned teaming (MUT) in a conflict against China along the LAC could be a game changer.

TACTICAL AIRPOWER LESSONS FROM RECENT CONFLICTS

Changing Paradigms and Doctrinal Shifts

The NATO campaigns of 1990s including wars in Gulf, Bosnia and Kosovo, altered military doctrines by signalling airpower as a primary instrument for force-projection and geo-strategic interventions. It was only a matter of time before nations not having such full-spectrum airpower capabilities would evolve asymmetric means to counter. This dominance of airpower is increasingly being questioned after almost two decades in the form of low-cost and easily procurable air-denial capacities. Just as proponents advocated air supremacy or even favourable air situation in time and space, asymmetric adversaries are touting air-denial in similar dimensions. The situation in Ukraine is testimony that despite far superior air power capabilities and sweeping control of the air, Russian air assets have been severely constrained in operating freely over Ukraine.[1]

However, that question and dilemma of attrition is facing many ground assets too because of the constant surveillance, fixing and targeting by an adversary’s networked systems, for example, weapons like US’ HIMARS against artillery and armour. A truly integrated force rather than just combined-arms seems to be the only way forward, along with attrition-resilience and supply chains to sustain intense combat over long durations.[2]

Analysts are even wondering if basic manned airpower precepts need to be reworked. Is a framework of mutual air-denial over critical periods leading to relegation of manned airpower's primacy? Is air superiority a done and dusted concept, even if it was never an end in itself but a means to a victorious end? Has leapfrogging technology in anti-aircraft sensors and missiles, autonomous and cheap unmanned platforms, among many others completely changed the variables in the equation? The answer lies in honest analysis of effectiveness and cost-benefit in terms of men, material and money.

Even more, innovative thinking, adaptability and quick-fire solutions at the tactical level have emerged as great disruptors and battle-winners. Decentralisation and dispersal are key words in any domain to survive an otherwise debilitating surprise attack in all domains. Jam-proof and secure networking of all these assets in real-time is crucial, as is built-in redundancy and flexibility of plans. It has again demonstrated the most important aspect in warfare - the cognitive domain.

Air denial does not come cheap. It has to be multi-tiered with multiple weapon options, and dense enough to overlap as an impenetrable matrix. Over larger areas this is an expensive and prohibitive option as seen in the consumption and attrition of large numbers of western supplied ground-based air defence systems. Uninhabited Aerial Vehicles (UAVs) seem to be a cheaper option than exorbitantly expensive manned aircrafts in diluting air-denial. However, as demonstrated in the myth cum failure of the Turkish Bayraktar, the adversary is on a fast-learning curve and adapts in time. In fact, the Russians, using longer-range and far cheaper 'one-way' drones like the Iranian Shahed have completely upset the cost-benefit equation for Ukranian air defence forces. With depletion in capabilities as a campaign progresses, swarms of expendable UAVs could overwhelm even multi-tiered air defences and cause confusion and attrition. This could then be followed up with combination of manned and unmanned platforms in offensive action through sanitised corridors.

AVIATION EMPLOYMENT DILEMMAS

In the first few days, air strikes were carried out **by Russia** against hundreds of targets including long-range radar installations, air defence systems, and logistics sites along main lines of advance. These were supported by electronic jamming and use of decoys. Ground Based air defence systems such as S-300 and S-11 were jammed or hit by missiles quite effectively.[3] Except for the initial week where concerted efforts went in for SEAD/DEAD to gain air superiority, once the first scenario of 'shock and awe' failed, the Russians began conserving efforts and limit it to the actual battle in the east of Ukraine. However, this permitted a regrouping and revitalising of Ukrainian ground-based air defence systems, which in turn allowed the attrition of Russian air assets to increase. It forced ground-attack and support missions to fly low but straight into the man-portable AD missile envelope. These had been supplied on a very large-scale by NATO, and NATO advisors backed by the best intelligence surveillance and reconnaissance (ISR) inputs of the west positioned these very efficiently.

According to western reports, in just a week eight aircraft were shot down by these **West-supplied weapons including** Su-25, Su-30 and Su-34 jets.[4] The Russian Air Force (VKS) had to resort to firing Kh-29 and Kh-59 missiles to hit fixed targets from standoff ranges using the Su-34 fleet. It tasked its Su-35S and Su-30SM fleets with Kh-31P and Kh-58 anti-radiation missiles to suppress radar-guided SAMs. According to western analysts, a mismatch in electronic spectrum seems to have been an issue in integrating air power into ground operations. For example, the electronic warfare (EW) capabilities used to degrade Ukrainian SAM systems caused disturbances in Russian ground forces communications causing fratricide.[5]

As per western studies of Russian military doctrines, the VKS has traditionally relied on dense and networked surface-to-air defence assets to cover ground-forces on the move, and along with army aviation assets, long-range ground-attack aircraft and helicopters serving as artillery for close-air support.[6] To allow the first-case scenario to unfold well, it was important not to give away the surprise element by excessive massing and preparation of aviation assets. In the author's opinion, avoiding collateral civilian damage especially in Russian-speaking areas marked for occupation was also a factor in how airpower was employed. However, **at the time of writing this analysis**, the AD capacities of Ukraine stand diminished due faulty overuse, VKS platforms have stepped up attacks using precision and non-precision weapons.[7]

Drone Warfare. As has been a noticeable trend in the last decade, unmanned cheaper and expendable platforms seem to be the way forward in modern warfare. If anything, the Russo-Ukraine War has only reiterated the complexity and uncertainty of modern conflict. Assumptions such as short-swift conflicts, non-vulnerability of supply lines and optimal stockpiling of armaments, and just-in-time maintenance concepts are being severely questioned.

Transparency on the battlefield is adding to the headaches of attacking forces. With deep-strike precision available, massed forces or strung-out supply lines are easy targets with disproportionate damaging effects on the battle scheme. A good example was in the 2020 Nagorno-Karabakh conflict. The Armenian-backed forces were on higher ground, well dug-in and camouflaged. But multiple tiers of sensors of the Azerbaijani military pinpointed them to be quickly destroyed with precision fires including loitering munitions and drones. However, it must be remembered that it formed only a part of the well-conceived adopting of emerging technologies and well-designed integrated-arms campaign that shocked and awed the Armenians.

An example of coming capabilities is the Russian S-70 Okhotnik drone, which flies at more than 1,000 km per hour with a range of over 6,000 km. It is equipped with an array of sensors for recce and targeting besides its own precision weapon payload of almost three tons. In teaming with the latest Su-57 fighter aircraft, it provides a new realm of manned-unmanned team concept. The Russian military is experimenting extensively with the swarm concept. It is based on multiple unmanned aerial flying platforms integrated as a single networked system self-contained for communication, reconnaissance and weapons (munitions) to strike enemy ground targets.

Another is the Iran-made Shahed-136, which has quickly become a major dilemma for Ukrainian forces. It costs about $30,000 USD with an estimated range of 2,000 kilometres. Such one-way attack drones challenge "the assumptions of modern air defense: that conventional militaries will primarily use a small number of extraordinarily capable systems, like advanced cruise missiles, strike aircraft, or UAVs, rather than large numbers of less capable systems."[8] One reason for the Saudis pitching for peace is such drone attacks against its oil lifelines. But nations are furiously working on optimised counters to such expendable platforms. For example, drone Hunter F700 (US) has radar backed by autonomous technology, and can precisely fire webs at drones.[9]

Similarly, emerging capabilities of loitering munitions have lapped up the Ukraine War as a proving ground. Suddenly, the tank, a symbol of mobility and lethality in manoeuvre warfare, finds itself in a supporting secondary role. No-contact engagements through loitering missiles are playing a dominant role. However, these are early days and successes, with expected advances and counters from better equipped and discerning air defence systems in the future.

Unmanned combat autonomous vehicles (UCAVs) seem to score over manned options in high-risk missions that suddenly become very plausible and cost-effective. It is not only cheaper in human and monetary terms but a game changing menu of strategic and tactical options. When employed as intelligent swarms they are able to beat most current air defence systems either by overload or hard-kill. Combining manned aircraft, UCAVs and loitering weapons offers posing even greater dilemmas for an adversary.[10] Undoubtedly, in the coming decade, force structures will veer less towards manned options.

Helicopters. The Russian helicopter fleets were extensively employed in all phases of the campaign albeit with changing tactics dictated by the ground-based threats. Ka-52s (Alligator), Mi-28s (Havok) and Mi-35s (Hind) attack helicopters carried out numerous hunter-killer missions initially, and switched to long-range rockets and stand-off missiles as the threat increased.[11] However, quick adaptability with self-protection suites and longer range weaponry has allowed the Ka-52 to operate effectively in thwarting the current Ukrainian counter-offensive.[12]

While UAVs have become the main reconnaissance and fire support platforms instead of helicopters, missions such as medical evacuation, air assault, combat search and rescue, will require helicopters for their speed and low-level stealth, agility, versatility, and payload carrying capability. In the mountains these missions would assume even more criticality. Therefore, the key issue of survivability need immediate addressing. A possible way could be unmanned platforms to carry out these roles in intense conflict zones.

Integrating Manoeuvring Forces. Since 2008, the Russian Armed Forces had changed from large formations to high-readiness combined-arms brigades (BTG). This approach was a lesson from its Afghan War.[13] However, with a third of army as conscripts, the concept faces challenges of effective integration in a short time.[14] Additionally, the rigidity in tactics, techniques and procedures impede adaptability when plans go awry.[15]

The timing and need for surprise and ambiguity at the strategic level affected operational and tactical preparations. "Time was insufficient for elements to conduct reconnaissance, establish flank and rear security, clear routes, pre-position supplies and conduct secure movement under the cover of air defences."[16] An Australian Army report identifies the following as early trend lines and lessons from the fog of the Russo-Ukrainian War:

- Ineffective and non-optimal combined-arms execution mainly due to communication issues of ad-hoc structuring, training and equipment interoperability.
- Rigid plans that did not adapt quickly enough. This was a result of the last-minute decision to invade or to keep the element of surprise.[17] The time to prepare for an integrated battle was too less.

- Russia's doctrinal dependence on artillery as a mainstay of operations got literally stuck in long queues on vulnerable roads. Ratios of artillery, armoured forces and infantry were inadequate for the missions and dense environment available.
- Heavy attrition and breakdowns in an intense campaign underline the dire importance of sustainment, logistics and supply chains.
- Drone usage and attrition in hundreds of thousands is complicating the tactical situation in fundamental ways.

A holistic look at these issues would clearly indicate that ground forces must now move from combined-arms to truly all-Services integrated operations and logistics in general, and MUT in lethal ones. The template in the mountains need detailed deliberations that follow.

MUT IN THE HIGH ALTITUDE CAMPAIGN

Fighting & Surviving. In classic Air-Land Operations, the counter-surface force operation (CSFO) missions such as battlefield interdiction (BAI), battlefield air support (BAS) and armed reconnaissance can be carried out by attack helicopters (AHs) in conjunction with other elements. Under normal circumstances, BAS at high altitude are high-risk missions for high-speed fixed-wing airpower, and they have evolved their own tactics to stay clear of SAM envelopes and deliver precision weapons and even dumb bombs from medium altitude and great distances. However, this mode is more suited for interdiction rather than pin-point targeting against concealed and static targets on hill or mountain tops.

AHs can employ ground hugging and terrain masking techniques, employing their defensive suites and stand-off weapons, and integrating with other land-based fire support for great chances of survivability in the mountains. A helicopter's ability to operate from forward basic helipads and Forward Area Refuelling and Rearming Point (FARRP) and ubiquity allow it to sustain a presence in the battlefield and impose a manoeuvre effect when employed in large numbers. The ability of helicopters to take off and land vertically and to sustain hovering and low-speed flight brings unique capabilities that make them particularly suitable for employment in a high altitude battle. Of particular relevance in this genre of conflict is the ability of helicopters to approach targets stealthily by flying in the nap of the earth, which offers them significant advantages over fixed-wing aircraft as long as they have adequate self-protection capability.

Terrain Dictates. In the mountains, terrain becomes a primary consideration and factor of warfare. The physical obstacles of terrain coupled with unpredictability of weather in the mountains only increase the degree of difficulty for combat operations. Mountains limit the freedom for rapid movements or manoeuvre, and thereby may hinder concentration of combat forces at a point of choice. Conversely, they may cause unplanned clusters at critical points. Not only does movement become predictable on mountain trails, vulnerability to counter attack on the flanks increase multi-fold. Battles in the mountains will primarily be for holding on to passes, dominating heights and roads, all under multi-tier fire from the enemy. The point here is that terrain will force compartmentalization of action, and therefore, the necessity of independent sub-unit action, including calling in of firepower (artillery or airpower) at a much lower level than the battle in the plains.

In the defensive mode, a planner would be able to effectively cover most likely avenues with a range of firepower. In a sense, the defender is able to effectively template the aggressor's major moves. Therefore, the aggressor would rely on air transport assets to launch operations into the flanks and rear areas. This would call for strengthening air-defence and anti-helicopter actions by the defender. A case in point is the introduction of Stinger missiles in Afghanistan and even the Kargil Ops. An attacker's game plan would include recce and surveillance of anti-air assets of the defender, and to neutralize them at the earliest with attack helicopters using terrain masking and stand-off weapons if required. UAVs and HUMINT would provide the intelligence inputs, some even real-time, to pairs of hunter-killer helicopters. Thus, pairing of helicopters and UAVs at the tactical level seems to be in order in the mountains.

An attacker's main body is protected in the flanks by security patrols and recce parties, which engage any ambush or flank attacks to destroy them and more importantly, to warn the main body of impending attacks. At such times, attack helicopters on call, coordinated by trained FACs on ground could more than thwart the enemy's moves and neutralise troop and gun placements on adjacent high grounds. Since terrain and few roads during the march do not allow sufficient turning movements to a large attacking force, integral light artillery and attacking air power are the only means to cater to meeting engagement with a counter-attacking enemy. A critical requirement would be availability of FACs on ground in adequate numbers (even at battalion or company level) while on the march.

A very effective way of achieving surprise in the mountains is enveloping detachments from the main body to the enemy's flanks. In case this is closely coordinated with firepower, the probes could detect vulnerabilities and provide windows to exploit. Attack helicopters would provide the means to protect the heliborne forces which would augment the enveloping detachment, as also the necessary fire power when exploiting the enemy's weakness. This calls for a high level of coordination at the lower level. Artillery de-confliction and co-ordination of multi-tiered fire support would have to be delegated to a lower level.

Artillery in mountains is constrained due to a number of reasons such as trajectory angles, difficulty of observation of hits to call out corrections and abrupt changes in weather. The terrain does not allow ideal placements of guns and may even force them to cluster near roads, making them ideal targets by air or counter-battery. These reasons among others will force decentralisation of artillery and would lead to lack of integral firepower at critical times. Such phases would require dedicated fire support in constricted space and time pockets. Attack helicopters/UAV at the Corpsor Div level could be delegated to brigade and battalion levels to cater to such emergent requirements.

An unmanned aircraft could act as a pathfinder for a main helicopter force, watching for anti-aircraft threats as the strike package moves to its objective. The picture seen by the UAV could be relayed back to helicopter crews, and they could adjust their route accordingly. The main strike force could also take advantage of targets of opportunity as they are discovered by the UAV. The unmanned system could provide targeting data to allow the crews to fire their weapons from stand-off ranges. If the UAV itself is armed, it could be instructed to engage threats directly. The current and future Indian Light Combat Helicopter should be aiming for many of the developments and capabilities listed above.

MULTI-DOMAIN INTEROPERABILITY

Multi-domain operations stretch across a spectrum of conflict from Hybrid Warfare to high-intensity combat situations, and require capabilities that are responsive and adaptive. Warfighting in such an environment is about networking in a secure redundant communication environment with other capabilities in every domain. The visualisation is that helicopter-UAV teaming in all their varieties and capabilities will play major roles from transporting in task-forces into battle to providing all kinds of support such as firepower and situational awareness. A truly integrated battle will mean all roles especially firepower support will be in coordination and synergy with fixed-wing unmanned and manned aircraft.[18] MUTs would be airborne sensors and shooters of the joint force.

Reflecting current trends across, a 2012 US Congressional Research Service report listed 31 percent of US warplanes in service as unmanned. The Israeli Army is clear that swarm operations by unmanned systems executing all battlefield roles would be core of concept in the future.[19] Any involvement of humans would mainly be dictated by high complexity of decision-making along with possible ethical and moral dilemmas.

Even medical and health support has undergone a paradigm shift after the First Gulf War. The concept of forward-basing large surgical units ahead was found unsound in modern-day battles.[20] Moving critical or even stabilised cases within the 'golden-hour' to hospital care in rear areas was found to be more efficient and effective. Larger helicopters with trained personnel and on-board ICU-care are now fulfilling this function. Looking ahead, unmanned helicopters would be resorted to when the risks are too high in a combat zone for manned ones.

Multi-Domain Operations essentially orchestrate and synchronise military with non-military activities across all domains to deliver unexpected converging effects. NATO now talks of Joint All Domain Operations (JADO), growing out of Multi-Domain Operations. It shifts the focus from 'multi-domain', which individual services tend to operate in, back on joint operations. Another concept being tested by the US military is of Mosaic Warfare which takes advantage of secure high-bandwidth networking to obtain an interconnected and interoperable force package, using the best of different platforms.[21]

Transparency on the battlefield is adding to the headaches of attacking forces. With deep-strike precision available, massed forces or strung-out supply lines are easy targets with disproportionate damaging effects on the battle scheme. A good example was in the 2020 Nagorno-Karabakh conflict. The Armenian-backed forces were on higher ground, well dug-in and camouflaged. But multiple tiers of sensors of the Azerbaijani military pinpointed them to be quickly destroyed with precision fires including loitering munitions and drones. However, it must be remembered that it formed only a part of the well-conceived combined-arms campaign that shocked and awed the Armenians.

FAST CHANGING WARFARE

Many analysts believe that "each age has its own wars and its own forms of warfare."[22] Some even predict that "significant ongoing changes in the security environment will alter the character of warfare beyond recognition."[23] Most breakthroughs in warfighting have come about due to convergence of numerous and varied fields that have transformed tactics and operational approaches to conflict. Many have even predicted a change in war's nature, heretofore considered a heresy. "The era of disruptive technologies, with the potential to change both the nature and character of war, is swiftly approaching."[24]

Some view disruptive and emergent technologies shifting the balance back to defence.[25] But there is always a danger of techno-romanticism i.e. relying on technology to provide all solutions and breakthrough innovations. The seesaw of defence-offence dominance has been part of military history, and no reason for it not to continue. The man behind the machine, and the limitless power of human innovation, will always be key to victory.

Fighting & Surviving in the Networked Age. An entirely new generation of network enabled weapons, possessing both precision and potency, and aided with real-time intelligence by pervasive sensors and high-speed analytics, is fast changing the nature of warfare. Most of the damage, both material and psychological, will happen before contact by troops. Importantly, all such weapons will have sensors and networking to enable real-time battle damage assessment, a vital issue in combat. The entire gamut of sensing, planning, deciding, and acting will necessarily need coordination across all five domains. However, a sixth domain (people) will need to be indoctrinated in this newer way of networked war fighting to achieve results on ground.

Information dominance will entail a myriad of issues such as the ability to protect own data and networks, high-speed processing, and dissemination capability in an uninterrupted manner, and denying all these to the adversary. Multi-domain synergised operations would demand shared battlespace awareness among men, autonomous machines and commanders of different sub-units. In such a networked high-pace battle, decision-making and allocation of targets and tasks will have to be quick while keeping a battlespace whole-picture framework. Only AI-enabled decision-making can do this for sustained long-term operations.

On the other hand, all the above also point to the vulnerability and susceptibility of networked weapons in particular to cyber or electro-magnetic attacks which could be in the form of jamming or a lethal attack, data corruption from a cyber-attack, or slowing down of network which affects guidance, navigation, and control of weapons in flight. It will also need a secure network incorporating encryption, redundant paths and nodes, and high reliability. Since accurate and secure navigation data will be the foundation of autonomous platforms and loitering or network-enabled weapons, security in the space domain including satellites and data flow is critical. So are the issues of bandwidth usage that need solutions for data prioritisation and sharing protocols, all being done at high speeds. Everything points to the imperative for a newer model of joint-targeting, and points of decision-making at different levels that caters to optimisation, timing and desired effects.

THE LAC BATTLE SCENARIO

2026 India-China War. This is a hypothetical scenario that brings out some ways to blunt a PLA offensive against Indian military. This is not holistic but serves to put the importance of manned-unmanned teaming in some perspective.

The PLA hoped for the following: mainly target Indian internal faultlines in its information campaign including selective cyber attacks; a quick and localised engagement based mainly on no-contact with shock and awe as primary aims, essentially a short teach-lesson template; and, seek Pakistan to deploy its military and asymmetric proxies to strain India. However, Pakistan was too engrossed and mired in its own economic, political and sectarian crises that were threatening to break it into pieces. India, reading the tea leaves well, aimed to set traps for causing maximum human attrition; planned unexpected incursions/forays, and disruptive controlled escalation; being prepared to accept initial setbacks but not get shocked or awed. All forces planned a quick resilient counter to put pressure on minds of the PLA leaders and personnel. The Kailash Heights episode in 2020 post-Galwan had shown the value of unpredictability in conflicts.

The expected onslaught of missiles by the PLA Rocket Forces (only limited numbers) were catered by a dispersion and disaggregation deployment of all Indian critical nodes. Because of sparsely populated areas along the LAC, a no-holds barred no-contact initial PLA onslaught was expected. PLAs superiority in unmanned systems, surveillance by space assets, and firepower (artillery deployable close to LAC was to be countered by a jamming and electronic warfare plan, help from the US military in light of newer agreements (e.g. Basic Exchange and Cooperation Agreement (BECA) on geospatial intelligence), and most importantly, the clear edge in airpower capabilities. Indian airpower benefited from numerous and dispersed lower-altitude airfields that allowed jets to be fully loaded. Since they were all close to the Himalayas, quick reaction and turnarounds benefitted the IAF.

Some key innovations had fructified that aimed to blunt the PLA superiority in drones, swarms, massed firepower, and cyber and electronic warfare. Indian forces were closely monitoring and fixing core PLA sensors and communication assets for own missile strikes. The Chinese main aim of defeating Indian networks was planned to be thwarted by a good redundancy plan and ability to move to a 'Plan B' of a low-communication state. This was premised on land and air supported stocking and supply of ammunition and sustenance kits for all weapon systems. MUT packages were kept on quick and adaptable readiness to cause maximum attrition backed by an agile integrated and disaggregated targeting cells across the LAC.

CONCLUSION

The Russo-Ukrainian conflict is instructive of how the character of warfare is changing rapidly, and yet many of its basic tenets and nature have remained constant. While technology has usurped many fundamentals, war has always been and will be about attrition, sustainment and logistics. This paper has attempted to study the tactical issues in integrating manned-unmanned teaming in battles in the mountains. A case for helicopter/UAV teaming has been examined.

It has been brought out that the see-saw between offence and defence is constantly evolving, and a key issue in military campaigns is adaptability and cognition-superiority. Deeper thought is needed in future force-structuring or one may face dire consequences of being out-manoeuvred. Open minds are necessary not only in tactics and employment, but mandatory in deliberating equipment-architecture and capability design.

The question of viability, effectiveness and survival of MUTs in intense battles has been debated. In the mountains such as the Himalayas, manned roles and tasks are still mostly indispensable despite the proliferation of UAVs. Their criticality in mountain warfare as part of the integrated battle and not just combined-arms concept has allowed some recommendations to be made along the way, especially in the scenario depicted.

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MUMT v/s A2/AD: EXPLORING TO DOMINATE IN A CONTESTED ENVIRONMENT

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The United States Army Aviation Centre (USAACE) defined MUMT in the 2013 MUMT Strategy Brief' as "the synchronised employment of soldier, manned and unmanned air and ground vehicles, robotics, and sensors" for "achieving enhanced situational awareness, increased lethality, and improved survivability."[1]

'Manned-Unmanned Teaming' (MUMT), defined by the IEEE, is the "coordinated use of manned and unmanned systems to achieve a common goal". The armed forces consistently employ this concept for accomplishments of various missions. Combining human judgement with automated machine processes is central to the MUMT approach. Search and rescue missions, environmental monitoring projects, and military operations are areas where humans and robots can work together to achieve greater efficiency and effectiveness.[2]

In recent years, the MUMT has garnered a great deal of attention to improve the security and efficiency of military operations. Missions that would be impossible for either system to complete alone can be accomplished with MUMT thanks to the synergistic collaboration between manned and unmanned systems through information sharing and the division of labour.

MUMT describes the cooperation between human operators on land, sea, and air and unmanned vehicles on land, sea, and air within the context of tactical operations to carry out missions and tasks. The MUMT system's adaptability is fully displayed over land, sea, and philosophy. However, the air domain has shown the most support for the MUMT concept.

In the early 2020s, software complexity increased significantly, allowing algorithms to perform an increasing number of mundane and repetitive activities that were previously the purview of humans. Significant improvements in unmanned technology have been made possible by developing relevant technologies. Though the changes have occurred since World War II's end, their notable momentum has been chiefly seen after the beginning of the 21st century.[3]

Growth Drivers for MUMT. Diverse foundations have contributed to the growth of combined human and robotic military capacities. Some of them are:

- Advances in sensor technology have made it possible for remote systems to collect more precise and up-to-date information, improving their situational awareness and capacity to make sound decisions.
- With the development of autonomous artificial intelligence, remote systems no longer need constant human intervention to carry out complex tasks. This allows people to focus on higher-level tasks like strategy planning and decision-making.
- Increase in real-time data transmission and decreases in latency have resulted from developments in telecommunication protocols and network topologies, paving the way for effortless cooperation between persons and distant systems.
- Easy-to-operate design techniques have impacted the evolution of Human Machine Interfaces, leading to more user-friendly and natural designs. This has allowed for more efficient information sharing between humans and remote systems.
- MUM-T ensures that manned platforms can keep their distance from the enemy's defences. It is assessed that weapons used with MUMT will be able to achieve their maximum capabilities due to the absence of ground-based obstructions. Effectively, the kill ranges are likely to get enhanced.

- As manned-unmanned teams become more prevalent, it became necessary to create programs that teach humans how to work efficiently with robots and teach robots how to communicate with humans.

The development of manned-unmanned teaming has been fuelled by technological progress, improved communication capabilities, and a commitment to user-centric design principles.

EXPLOITATION OF MUM-T IN OPERATIONS

Using a combat drone to extend the power and reach of an inhabited fighter while still keeping a human in charge of firing decisions is an increasingly common practice among militaries. The Russian S-70 Okhotnik, a UCAV, was deployed on the Ukrainian battlefield on June 27, 2023. During this operation, it targeted Ukrainian military installations located in the regions of Sumy and Kremenchuk.[4]

A prototype of the Russian S-70 Okhotnik combat drone is expected to enter military service in 2024 with the promised capability of attacking air and ground targets. The manned-unmanned teaming will be part of Russia's approach to network-centric war. The Okhotnik and the Su-57 will share their targeting and sensor data, allowing each aircraft to perceive everything the other's sensors captured. Each Okhotnik can carry up to 4,400 pounds of bombs, considerably more than an MQ-9 Reaper in US service can deliver.[5]

In the Azerbaijan-Armenia conflict, a notable development occurred when human and unmanned aircraft collaborated effectively, resulting in a swift resolution to the protracted disagreement. The recent success of the Turkish-made TB-2 UAV system, employed jointly by the Turkish and Azeri air forces, is a significant milestone.[6]

Nevertheless, most of the MUMT projects are in a nascent stage and focusing on the processes of conceptualisation, design, and validation. The use of MUMT in the Gulf War, the Nagorno-Karabakh conflict, and the Russia-Ukraine conflict (RUC) was incidental or an improvisation of various dimensions of MUMT. For example, drones were launched ahead of attack helicopters or tank columns. The credible communication link between these elements for data transfer and control was missing. The actual MUMT mission may be possible by 2024.

Indian MUMT Project 'HAL CATS'. Indian aerospace firm Hindustan Aeronautics Limited (HAL) is developing a MUM-T system it calls the "HAL Combat Air Teaming System (CATS)" in partnership with the private sector. CATS is an overarching system whose central node is an LCA. "Mothership for Air teaming exploitation" (MAX) refers to the two-seater Tejas Mk1 Trainer. For the Tejas Mk-1A to serve as a MAX in CATS, its command-and-control infrastructure is now undergoing modifications. The operator of each LCA's weapon system in Tejas MAX will operate the UAS/swarm drones. A network of highly sophisticated autonomous drones will be linked to a fighter plane through the CATS, which may employ them in air-to-air, sea-to-air, and ground-to-ground combat. The Tejas two-seat trainer is being fine-tuned as part of an effort to combine human and robotic flight.[7]

MUMT Projects for Other Nations. Various MUMT projects of various countries, which are still to be inducted in warfare operations

- The US Army has implemented MUM-T tactics on the AH-64D Longbow Apache helicopter gunship. The Apache Block II effectively showcased the capability of transmitting video to the One System Remote Video Terminal (OSRVT) by utilising the Efficient Tactical Common Data Link (TCDL). Teaming of MQ-9 Reaper and F-35 Lightning II for MUM operations is also under progress.[8]
- Russia is involved in a joint flying venture encompassing a stealth fighter aircraft called the Su-57 and an attack UAV known as the Okhotnik. Israel's Elbit Systems has developed UAS swarms using Remote Autonomous Systems (RAS) technology. Israeli MUMT project involves Heron TP and F-16. Turkey has successfully demonstrated an autonomous taxi and take-off roll for its Kizilelma Fighter UAV. The Chinese project is with Wing Loong UAV and J-20 Fighter MUMT, while the United Kingdom's MUMT project is teaming with Protector

UAV with Typhoon. France's 'Système de Drone Aérien' (SDA) is the experimentation of MQ-9 Reaper and Rafale MUM teaming projects. Europe's Future Combat Air System (FCAS) programme is in progress, where France, in collaboration with the UK, is facilitating the advancement of a series of interconnected aerial vehicles. South Korea is now engaged in a project to develop a stealth UATV.[9]

ANTI-ACCESS/AREA DENIAL (A2/AD)

The concept of A2/AD entails implementing a military approach to obstructing or hindering an opponent's capacity to gain access to or conduct operations within a particular geographical region. Western strategic planners widely use the term "A2/AD" to refer to a strategic approach involving utilising a range of interconnected technologies, such as missile sensor guidance systems, to impede the freedom of operations. The primary objective of 'A2/AD' is to deter potential adversaries from deploying military forces 'in close proximity' to or within the defined region.[10]

A2/AD consists of two components – 'A2' and 'AD'. 'The Anti-Access (A2)' concept is employed 'to deter or restrict hostile forces from gaining access to a designated conflict zone or operational area'. 'The area denial (AD)' component of the A2/AD strategy aims to' impede or restrict the enemy's ability to manoeuvre within a designated operational area freely'. In its fundamental essence, A2AD refers to a defensive instrument or strategic approach employed to impede an adversary's ability to obtain entry into various domains or move unrestrictedly within the realms of land, sea, space, cyber, electromagnetic warfare, maritime, and air. The concept of A2AD has been employed throughout history. Nations like China and Russia have successfully established and fortified a comprehensive A2AD network to safeguard their territorial boundaries. However, it is common practice for all major military forces to employ a variant of A2AD strategies to protect their personnel and assets.[11] Numerous countries, including the United States, Russia, and Israel, widely operate the concept. As technology progresses, so do A2/AD domain capabilities.

WEAPONS DEPLOYED IN A2/AD

Any weapon or technology can be utilised for A2AD purposes if it effectively impairs or limits the movement of entities through a given area. The product is designed with multiple layers to enhance its effects. Some examples of A2AD capabilities include layered coastal defence systems designed to counter threats from ships, anti-tank systems to deter armoured vehicles, and layered air defence systems to protect against airborne threats.

A2/AD plans usually use various weaponry to deny access to their enemies and create rigorous operational conditions. The following is a list of some examples of weapons that are often used in A2/AD systems, along with the essential attributes of each weapon:

- **Integrated Air Defense Systems (IADS)**. IADS use SAMs, radar systems, and command and control networks to defend against airborne threats. These systems have multiple levels of defence combat targets at varying altitudes and ranges. The well-known IADS encompass the Russian S-400 and S-300, the U.S. Aegis Combat System, and the Israeli Iron Dome.
- **Surface-to-Air Missiles (SAMs).** SAMs can target aircraft, drones, and other airborne threats. They are usually used in land-based missile batteries or naval boats. SAM systems use radar and may engage at various ranges and heights Prominent surface-to-air missile (SAM) systems encompass the Russian S-400, U.S. Patriot, and Chinese HQ-9.
- **Ballistic Missiles**. A2/AD plans can use short-range (SRBMs), medium-range (MRBMs), and intercontinental ballistic missiles (ICBMs). These land-based missiles can carry conventional or nuclear bombs. They threaten enemy forces and infrastructure with long-range strikes. Illustrative instances encompass the Russian Iskander, Chinese DF-21, and North Korean Hwasong series.
- **Anti-Ship Missiles (ASMs)**. These are employed to destroy navy vessels. Land-based launchers, aircraft, submarines, and surface ships

launch them. ASMs can engage ships at sea due to their long ranges, rapid speeds, and robust guidance systems. Some examples of Anti-Ship Missiles (ASMs) are the Chinese YJ-18, Russian Kalibr, and Iranian Noor missiles.

- **Anti-Access Mines**. These mines prevent enemy naval or amphibious forces from approaching, landing on a coast, or entering a canal. These mines can be launched from ships, aircraft, or submarines and have sensors that engage nearby targets. Illustrative instances encompass the U.S. Mark 60 CAPTOR and the Russian PMK-2.

It is essential to consider that the exact weapons used in A2/AD can differ from country to country, region to region, and even with the progression of technology.

THE VULNERABILITIES OF A2/AD

The A2/AD strategy, as it refers to a military system to prevent or impede an adversary's ability to enter or operate within a contested region, usually relies on the utilisation of long-range precision-guided weaponry, air defence systems, and various other capabilities. Although the A2/AD technique represents the defensive approach, it has flaws. The following are several potential vulnerabilities that are related to A2/AD strategies:

- The sensors, command and control, and weapons systems that make up A2/AD are all vulnerable to the opponent's compromise. The A2/AD force's situational awareness and response capabilities can be hampered by the enemy's employment of cyberattacks, jamming, or kinetic strikes against the network's communication nodes, radars, or launchers. The adversary can also deploy stealthy or decoy platforms to avoid or trick the A2/AD network's sensors and missiles.
- The enemy's ability to take advantage of A2/AD's assets and resources depends on their quantity and quality. For instance, A2/AD can employ many low-end, inexpensive, and susceptible assets or a small number

of high-end, premium, and capable weapons. The A2/AD force's low-end assets can be overwhelmed or flooded by a barrage of enemy SWARM drones or missiles, while the force's high-end assets can be whittled down or rendered useless by attrition or deceit.

- Coordinating and synchronising A2/AD's actions and capabilities is a difficulty the adversary can exploit. The A2/AD framework, for instance, can be governed centrally, in a coherent but inflexible fashion, or decentralised, in a flexible but chaotic manner. The A2/AD force's command and control structure can be brought into turmoil if the enemy employs a combination of tactics, such as Muti-mode multi-directional attacks at once or using a wide variety of domains and ranges, or if the adversary is quick to exploit weaknesses in the A2/AD force's operations and capabilities.

As an illustration, Anti-Access/Area Denial (A2/AD) can be implemented through two distinct approaches: a centralised method characterised by coherence but rigidity or a decentralised approach characterised by flexibility but potential chaos.

COUNTERMEASURES AGAINST A2/AD SYSTEMS

Various countermeasures can be implemented to mitigate the effectiveness of A2/AD systems. The primary objective of these countermeasures is to diminish the efficacy of A2/AD methods and enhance the capacity of an opposing force to infiltrate or deactivate defensive capabilities. The following are several illustrations:-

- **Stealth Technology**. Stealth aircraft and warships refrain from radar detection. Stealth systems can attack targets or gather intelligence by drastically reducing their radar signature through shape, materials, and coatings.
- **Electronic Warfare (EW)**. Jamming radar signals, spoofing enemy sensors, or disrupting communication networks can deceive A2/AD systems. EW can allow friendly troops to exploit or negate A2/

AD defences by reducing the adversary's situational awareness and command and control.

- **Long-range Stand-off Weapons.** Cruise or hypersonic missiles allow the enemy to engage A2/AD systems outside the defended area. These weapons may incapacitate crucial nodes, infrastructure, and sensors, weakening A2/AD systems and defensive posture.
- **Cyber Operations**. Cyberattacks against command-and-control networks, communication infrastructure, or computers can impair A2/AD systems. Infiltrating or manipulating these networks might damage A2/AD defences, disrupt coordination, or trigger false alarms or misdirection.
- **Saturation Strikes**. Overloading A2/AD systems with simultaneous or successive attacks might exploit their weaknesses and boost penetration. Adversaries try to overwhelm interceptors, sensors, and other defensive systems to penetrate and engage targets.
- **Special Operations Forces (SOF)**. SOF can covertly deactivate or sabotage important A2/AD assets. Targeted strikes, reconnaissance missions, and sabotage operations against important A2/AD network nodes can reduce their effectiveness and defensive capabilities.

MUMT AGAINST A2/AD

The concept of A2/AD encompasses a range of operations and capabilities, including but not limited to air defence systems, radar technologies, missile systems, naval minefields, electronic warfare tactics, cyber offensive measures, and space-based weaponry. Nevertheless, the A2/AD system is neither invincible nor impenetrable and possesses some flaws that adversaries can exploit.

A2/AD uses defensive measures to prevent an enemy from entering or moving through a given area. To solve such challenges, MUM-T integrates manned and unmanned strengths. MUM-T improves situational awareness, operational flexibility, and operator-unmanned system coordination by merging manned and unmanned platforms. Manned platforms offer cognitive capacities, experience, and decision-making, while unmanned systems offer reach, persistence, and high-risk operations. Unmanned systems to carry out operations that would be too hazardous or challenging for manned platforms; MUM-T can fight back against A2/AD. When in action with manned platforms, unmanned systems can perform reconnaissance, surveillance, and target acquisition in real-time, judgements may be made, and threats can be engaged more securely.

Unmanned systems can saturate the enemy's defences and divert their focus with multiple drone attacks. Exploitation of Loitering Munition Drones may also be resorted to enhance the lethality. They can boost the manned platforms' efficacy and overwhelm A2/AD systems with electronic warfare, decoy operations, and weapons platforms.

Human operators on manned platforms can be protected from A2/AD attacks by relying on unmanned equipment to conduct preliminary surveillance and target acquisition.

By consistently Monitoring enemy activities and detecting developments or changing threats, Unmanned systems can provide persistent surveillance over an assigned region. Man-operated platforms can get this data in real time to better adjust their tactics and responses against A2/AD weapons.

MUM-T allows for distributed operations, which is the simultaneous use of manned and unmanned platforms across a large geographical area. As it becomes more difficult for an enemy to single out and destroy a dispersed force, this distributed strategy can help counter the threats A2/AD systems pose.

The weaknesses of the A2/AD approach could be targeted and exploited to diminish or nullify its effectiveness. Disruptive technologies represent a highly productive approach that should be implemented carefully and carefully. The utilisation of MUMT operations has the potential to achieve the desired objectives effectively.

MUM-T enables mission planners and operators more versatility and adaptability. Unmanned systems are flexible in deployment and positioning, allowing them to adapt to changing operational requirements and take advantage of openings in the enemy's A2/AD defences.

Unmanned devices can be used as a force multiplier, overwhelming the enemy's defences, and drawing their focus elsewhere. They are exploiting Stealth with Disruptive Technology. Their usage in electronic warfare, decoy operations, and weapon platforms can boost the performance of human-operated systems and render A2/AD defences useless.

THE VULNERABILITIES OF MUMT

MUM-T's success in combating the A2/AD methods depends on unmanned system capabilities, command and control system integration, and strategy adaptability. Adversaries may also create MUM-T countermeasures. Therefore, continual research, development, and innovation are essential to staying ahead in this field. To achieve the highest degree of equipment preparedness, pre-emptive measures must be initiated to check the adverse effects of likely vulnerabilities that manifest within MUMT systems. These are:

- **Communication and the Need for Coordination**. Communication and coordination failures are MUMT systems' most significant vulnerabilities due to their variations in communication protocols and data formats; manned and unmanned systems face challenges in sharing information and coordinating. In conflict zones, manned-unmanned equipment communication delays might be problematic.
- **Cyber-Attacks**. Continuous internet access makes unmanned systems vulnerable to cyberattacks. Cyberattacks might turn off unmanned systems or take control, putting manned-unmanned teams at risk.
- **Exposure to Hard Kill**. MUMT systems are exposed to Risks from hostile fire and IEDs. Safety issues exist in unmanned systems. Using unmanned devices may also increase collateral damage due to hitting unwanted targets.
- **Aeromedical Problems**. During a MUMT mission, pilots flying manned platforms alongside an unmanned aircraft (UA) may face aeronautical

challenges like task saturation and excessive workload. In 2015, the US Army Aeromedical Research Laboratory (USAARL) studied the Human Factors (HF) and aeromedical challenges of using MUMT applications. MUMT pilots may face many problems, according to the USAARL. These issues include visual overload, increased workload, task saturation, distraction, decreased flying situational awareness, and motion sickness. USAARL also warns that processing contradictory sensory information, such as aerial platform motion cues and unmanned aircraft (UA) orientation, and other potential outcomes from enhanced cockpit UA compatibility may increase the risk of Spatial Disorientation (SD).[12]

RECOMMENDATIONS

The efficacy of MUM-T in fighting A2/AD strategies is contingent on several elements, including the sophistication of the unmanned systems, the cohesiveness of the command-and-control structures, and the flexibility of the tactics employed. It's also possible that MUM-T's foes will figure out how to counteract it. Thus, continuous research, development, and invention are required to preserve competitive advantage in this field.

To accomplish all envisaged military objectives to counter A2/AD, these may be factored into the design of MUMT. The following measures need to be considered to address the operational and maintenance limitations of MUMT:

- **Exploring the Tactics**. Validation/testing and revaluation of techniques are essential for improving MUMT procedures. One organisation should be tasked with devising strategies for carrying out the various components of the objective.
- 'The Tactical Air Combat Development Establishment (TACDE)' is a specialised unit within the Indian Air Force dedicated to advancing and refining aerial combat capabilities. This institution can potentially be assigned the responsibility of developing MUMT tactics.
- **Managing Airspace Management Challenges**. New procedures, tools, and regulations must be created to manage airspace for manned and

unmanned teaming operations. All stakeholders must cooperate to ensure no fratricide and the safe integration of manned and unmanned aircraft inside the targeted airspace.

- **Maintenance and Logistical Operations**. Maintenance and logistical operations can prevent unplanned downtime and boost operational availability by planning and providing replacement parts, technical assistance, and experienced people. The demand for MRO and logistics support for manned and unmanned assets needs to be addressed.
- **Training and Skill Development**. The smooth operation of MUMT requires a skilled crew. Develop essential team members' education and training to effectively combine human and unmanned systems. Exercise will help operators manage unmanned assets and comprehend human and platform constraints.
- **Research and development (R&D).** Regular R&D enhances the MUMT's productivity and efficiency. This requires cutting-edge research, realistic experimentation, and hypothesis testing. Focus on improving sensors, data processing infrastructure, and real-time data fusion algorithms to strengthen the ability to counter A2/AD.

Future research in MUMT will likely yield improvements in autonomy and interoperability, ultimately leading to deeper levels of manned and unmanned system integration.

Even though MUM-T has several benefits, it's crucial to consider that A2/AD approaches are constantly developing. The effectiveness of MUM-T could be reduced if adversaries devise countermeasures or modify their strategies. Therefore, maintaining an efficient counter to A2/AD requires a holistic approach that integrates MUM-T with other operational concepts like electronic warfare and cyber capabilities.

CONCLUSION

The MUMT uses both human and robotic resources to complete a task. It's becoming increasingly clear that this is one of the most transformative technology developments for aerial combat in decades. Adaptable unmanned gadgets, as part of an extensively used intelligence network, will act as a "force multiplier" for crewed aircraft, boosting the team's efficiency and protecting the pilot from harm while maintaining command.

A2/AD refers to using defensive measures to deny an adversary access to a specific area or their freedom of movement. The A2/AD strategy encounters a significant obstacle in effectively coordinating and synchronising its manoeuvres and capabilities, which may be susceptible to exploitation by adversaries. MUMT combines the strengths of both manned and unmanned systems to overcome these challenges. MUMT can indeed be an effective strategy. Exploring potential strategies for incorporating the MUMT into alternative missions warrants additional consideration. Furthermore, it is imperative to acknowledge that the relentless progression of technology will persistently enhance diverse platforms and sub-systems with the ultimate objective of optimising the operator's workload.

However, MUM-T's success in combating A2/AD methods depends on unmanned system capabilities, command and control system integration, and strategy adaptability. Adversaries may also create MUM-T countermeasures. Therefore, continual research, development, and innovation are essential to staying ahead in this field.

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FUSING INTELLIGENCE: DRONES, MANNED ASSETS & SATELLITES

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Abstract
Elaborate, actionable and timely intelligence is essential for planning. preparing and execution of all domain operations. Many different types of platforms like UAVs, manned platforms and satellites are employed to collate intelligence. All intelligence platforms are not the most suitable during different operational environments. Most of them have capability gaps which can be plugged by other platforms and sensors employing different segments of electromagnetic spectrum. Fusing of intelligence from different intelligence platforms and their employment options during different phases of operations would ensure the most optimum collation of the actionable and timely intelligence. This paper brings out the way forward to fusing intelligence from different platforms and sensors, for acquiring comprehensive intelligence during all operational phases.

INTRODUCTION

Intelligence (int) has always been an important element of warfare. It is an ongoing and continuous activity which pervades during peace, 'no peace no war' (NPNW) environment and during hostilities. However, the priorities and targets for intelligence, change during different states of alert. All phases of war fighting from preparation, planning, execution and review of operations require updated, accurate and actionable intelligence at all levels for commanders to work out military strategy and facilitate operational decisions and for combatants to enhance situational awareness.

To observe the enemy dispositions, intentions and activities, intelligence resources usually exploit 'high ground' to cover larger area and obtain clearer 'picture'. Historically, this activity started with balloons, then graduated to aerial platforms and with launch of satellite in 1957, it transcended the space during the cold war era, to observe deployment of ballistic missiles and provide early warning of missile launches. Unmanned Aerial Vehicles (UAV) came in as inexpensive platforms for intelligence, surveillance and reconnaissance (ISR) missions during the Vietnam War and during the Arab-Israel wars. During Bekaa Valley campaign of 1982, the Israelis employed UAVs so ingeniously, that the world took notice of UAV's operational potential. Ever since then, UAV designs and capabilities have improved tremendously and their shapes and sizes have been tailored to match the user intelligence requirements. While High altitude Long Endurance (HALE) UAVs can stay aloft for more than thirty-six hours streaming live videos and other data continuously, small, backpacked UAVs can be easily launched by soldiers to monitor border area and perimeter security and gain immense tactical intelligence. Significant advances in Information and Communication technology have tremendously enhanced the intelligence data collation, analysis and dissemination process. Rapid advance in sensor technology now provides UAVs with carriage of multiple spectral sensors for observation through all types of weather, including clouds, fog, dark night and foliage.

The intelligence requirements of the armed forces are governed by the scope of their operations, which will further dictate the type of target, depth of area to be monitored and the time criticality. During peace, when operating in a benign environment, any asset could be employed within own borders for regular intelligence updates. However, during hostilities, while operating in a contested and hostile environment, the survivability of the platform and time sensitivity would be the main considerations amongst other factors, for employment of the platform and sensors. Major intelligence platforms are generally low-density high demand assets, procurement of which requires deep analysis of their employment considerations. It is, therefore, important to analyse the employment considerations of different intelligence platforms during various contingencies and consider the ways to integrate and optimise their employment.

INTELLIGENCE PLATFORMS

UAVs. Many categories of UAVs are operational for specific int requirements. HALE UAVs have an endurance of thirty-six hours, operational altitude of sixty-five thousand feet and can carry an all-weather payload of up to 700 kg. RQ-4 Global Hawk HALE UAV has been employed by the United State Air Force (USAF) as a complement to the U-2 'Dragon Lady' spy plane. Medium Altitude Long Endurance (MALE) UAVs have an endurance of thirty hours and operating altitude of twenty-five thousand to thirty-six thousand feet. The operating speeds are generally low in the region of sixty to eighty knots. Other small tactical UAVs vary from fixed wing to rotary wing types. Bigger UAVs require prepared runway for launch and recovery while the small ones could be launched by catapult or by soldiers themselves. Indian Armed Forces have acquired MALE class and tactical UAVs with many different payloads operating in visual, electro/optical, infra-red and radar regimes. Passive signal intelligence (Sigint) surveillance capability is generally embedded in most of the tactical UAVs. The operational infrastructure for these UAVs includes Ground Exploitation Station (GES) and data link for communication with UAV. GES houses internal pilot to control the UAV flight, and System Operators to manage on board sensors for the required int task. The Indian Army has procured large number of mini-UAVs for perimeter security and tactical intelligence in proximity of troops and to monitor terrorist activities. During peace time, the UAVs are versatile and economical assets for collating intelligence across the border, due to their large persistence, ease of operation from airbase and controllability beyond line of sight. Imagery quality is high, and the payload controller can judiciously control the sensors for as per int requirements. However, the UAVs presently employed by the Indian Armed Forces have limited sensor range to monitor across the border. In depth targets for standoff precision weapons may be beyond the range of these UAV sensors. During hostilities the UAVs are vulnerable to hostile action due to low speed and lack of self-protection capability. Jet powered high speed UAVs equipped with self-protection suit will have better chances of survival. On 19 June 2020, the versatile and expensive RQ-4 Global Hawk HALE of the USAF was shot down by the Iranian Forces over the Strait of Hormuz.[1] The second vulnerability is the communication datalink between the GES and the UAV, to jamming and interference by hostile forces. In December 2011 Iran forces were successful in taking control of the US UAVRQ-170 Sentinel and forced it to land in Iran.[2] The mounting attrition rate of surveillance UAVs during the ongoing Russia Ukraine War substantiates the vulnerability of int gathering UAVs during hostilities. Mini UAVs can be employed during operations to obtain the valuable battle transparency for better situational awareness as they are expendable entities.

High Altitude Pseudo Satellite (HAPS). Recent incident of the Chinese Balloon overflying the airspace of the USA during January 28 - February 04 2023 has drawn attention of the world to the stratospheric gap between the normal operating heights of UAVs and deployment of Low Earth Orbital (LEO) satellites, which could be exploited for persistent surveillance of very large area in an economical manner. While the balloons have limited manoeuvring and controllability, there is significant development going on to employ High Altitude Pseudonymous Satellite (HAPS).“*High altitude pseudo satellites possess improved functionalities than traditional satellites. HAPS can be maneuvered to fly in different directions and locations. Thus, HAPS are ideal for a range of applications, including surveillance, communication, and environmental monitoring. They can be powered by solar panels and other renewable energy sources. Thus, they are cost-effective as compared to traditional satellites.*[3] In India, Hindustan Aeronautics Limited (HAL) has teamed up with New Space Research and Technologies Pvt Ltd to develop solar powered HAPS that could stay aloft for months.[4] These platforms have extensive growth potential for both military and civil applications. It can be effectively employed during peace and NPNW environment. However, it is likely to be a vulnerable target during hostilities.

MANNED PLATFORMS

Fighters/Bombers. Historically, balloons were employed in the nineteenth century to observe the disposition of enemy troops. Once the flying machine was invented, aircraft were employed extensively for int gathering due to better performance, survivability, and response. During the World Wars and subsequent conflicts, many available fighters and bombers were modified to take on the reconnaissance (Recce) role. Spitfires, F-4 Phantoms, and the Indian Canberra bombers were appropriately modified as reconnaissance platform. As Surface to Air Missile (SAM) technology matured, very high-altitude Recce aircraft like U-2, MiG 25 Foxbat were inducted to intrude across the border and gather valuable imagery of enemy targets without threat from SAMs. The Indian Air Force (IAF) acquired many Recce Pods which could be attached to the fighters for specific recce missions. Fighter/bomber class of aircraft score over the UAVs for ISR role during hostilities, as they have self-protection capability and can be employed both during peace and war. They fly at much faster speeds and can control the on board sensors as per the mission objectives. Low level intrusions across the border to 'film' targets for the best images can be done only by fighters. In the past the imagery and data gathered through these missions required a large processing time to produce and analyse images. The USAF developed a secure, jam resistant 'Joint Tactical Information Distribution System'(JTIDS) in the seventies to transfer imagery data online to other aircraft and command and control centres (C2C). Today digital imagery is transferred real time to other airborne 'shooters', and Command and Control Centres. Versatility of fighters and better performance capabilities, make them an excellent recce asset during all phases of operations. However, they are expensive assets that could be pulled out for other high priority offensive/defensive roles. The IAF had

106 Strategic Recce Squadron equipped with dedicated photo recce PR 57 Canberra bomber, which provided very valuable imageries during Indo-Pak 1971 War, both in the West, in the East and during Kargil War.[5] The squadron has now been re-equipped with fighter aircraft.

Transport Aircraft. Business jet class and bigger air transport platforms are specially configured for Intelligence, surveillance target acquisition and reconnaissance (ISTAR) task to provide vast data through optical, infrared, radar and electronic signals and detect targets on the ground, in the air and over maritime areas. Multiple sensors and advance communication systems on board make it a value asset for intelligence during all-weather operations. There are many 'sensor controllers' on board who can monitor the data and manipulate the sensors for better results. As they fly at high altitudes of fifty thousand feet, and have range of at least ten thousand km, very large multi-spectral int data gets collated in a short time. The Indian Navy (IN) P-8I Maritime Patrol Aircraft (MPA) has been derived from the Boeing-737 800 transport aircraft. ISTAR platforms are strategic assets that provide valuable inputs to the commanders for planning and operational decisions. During hostilities, these high value assets (HVA) with embedded self-protection suite are employed in depth of own area and could be provided protection by own fighters. Many transport aircraft can be modified to undertake intelligence missions and some of them have 'roll on roll off' palletised equipment for special missions. Many countries have opted to configure the C 295 transport aircraft for ISR role.[6] The C 295 aircraft have been acquired by the IAF and induction will start within 2023.

SPACE BASED ASSETS

Satellites. Space is the 'highest ground' available for intelligence inputs and surveillance. Uncontested environment of space provides excellent option for deployment of imagery satellites, without violating sovereignty of any nation. Satellite imagery has been used copiously in almost all operations, and the imagery satellite capability has been improving tremendously over the years. In the past, there was delay in obtaining imagery inputs from satellites, just like the air breathing platforms. It is believed that the US could not provide satellite imagery to Israel during the Yom Kippur War of 1973 as the photographic films had to be recovered and developed further before obtaining the imagery results.[7] Present day Imagery satellites have achieved centimetric resolutions and the data is available in real-time to the operators and the leaders. However, LEO satellites that provide the best imagery have limited dwell time of few minutes over a specific area and revisit period of the same area could be many days. To obviate this delay, 'cluster of satellites can be launched to reduce the revisit time. For better satellite inputs, the USA deployed over one hundred military satellites during the Gulf War. India is well on the way to exploit outer space for military applications. Having learnt from the lack of satellite imagery during the Kargil War, India developed indigenous satellite imagery capability and launched the first Technology Experiment Satellite in October 2001.[8] This was followed by 'Cartosat' series of imagery and the 'Risat' (Radar Imaging Satellites). The space assets are indeed quite expensive and are technology intensive in many fields. Total numbers for intelligence satellite would always be limited. Their path in the space is usually predictive during peace and the enemy could conceal the activity from their gaze, as India did towards preparation of nuclear test at Pokhran test Range in 1998.They are, nevertheless, integral elements of all military operations as they provide intelligence, position and communication links that support net centric operations.

IMINT REQUIREMENTS OF THE ARMED FORCES

Peace Time. Data base and intelligence update is an ongoing process during peace for strategic and tactical operation planning, as well as to for perspective procurement plans. Electronic Order of Battle (EOB) which includes Radars deployment, SAMs, Communication Centres and Ground Control Stations, is required to be updated all the time as the control of the air during operations would require degradation of the hostile Air Defence Assets. Deployment of the Army formations, Logistic nodes, fuel storage and Ammunition Dumps are some of the important assets to be monitored. Infrastructural development and hostile Armed Forces disposition are crucial intelligence inputs for planning operations. These requirements could be termed as 'strategic intelligence requirement' during peace', for this article. The Army is required to keep the borders under surveillance continuously to keep the battle space awareness updated, detect Kargil like intrusions and the Chinese attempts of occupying unmonitored areas. Intrusion by anti-national elements from across the borders require continuous surveillance. These could be termed as 'border area intelligence' for this article. The Navy is required to monitor the maritime area for submarines, ships, and other elements inimical to the national security. This maritime patrolling is again a continuous activity. As the armed forces have inducted large number of precision weapons with stand-off ranges, it is important have the precise location of the likely targets updated all the time. This could be termed as 'target intelligence'.

During War. During transition to war, ISR assets would be deployed more vigorously to monitor the enemy disposition changes, movement, and changes in the EOB. During war, timely intelligence would be critical to see through the fog of war and take operational decisions. As the AD assets are much more mobile and wartime deployment of these assets could be different from the peace time. Updating the EOB is, therefore, highly prioritised requirement of the Armed Forces. Battle Damage Assessment (BDA) through ISR operations would be an additional task to decide on further attacks. It is important to correlate intelligence with other sources of Sigint, Synthetic Aperture Radar and demand for imagery intelligence of the pinpointed area to achieve the results faster.

OPTIMUM EMPLOYMENT PHILOSOPHY OF ISR ASSETS

For peacetime strategic intelligence, ISTAR aircraft, other Signal Intelligence (SIGINT) platforms, and Satellites would be employed to keep the intelligence updated. Fighters with ISR pods could be flown closer to the border to supplement or further investigate inputs derived from other platforms and other intelligence inputs. These assets would also be employed to update the 'target intelligence' especially for targets in depth for standoff precision weapons. HAPS would be the most economical and suitable platform for peacetime intelligence task. MALE and Tactical UAVs are best suited for 'border intelligence' and to monitor Naxal activities. These assets could be supplemented by suitable fighters for all weather monitoring and for any special task. Small UAVs would be used by the troops and other paramilitary forces for obtaining better situational awareness against terrorist movements. Maritime patrolling and Maritime domain awareness is ensured by satellites, MPA, suitable MALE class of UAVs and helicopters carrying suitable payloads. There would always be special requirements during peace to monitor natural calamities, for which, the most suitable platform could be employed as there is no risk of hostile action against the platforms. During war, in addition to satellite imagery, ISTAR aircraft, Fighter Recce platforms and other collateral assets earmarked for operations would be employed. Big UAVs would have to be judiciously and selectively employed to update intelligence.

PRESENT GAPS

Considering the vast border of seven thousand five hundred kilometres with hostile neighbours and perpetual intrusion by anti-national elements, India lacks ISTAR types of strategic intelligence platforms. UAVs procured by different services are not inter operable as they do not have common data links. Due to this gap, there are prohibitive delays in disseminating tactical intelligence. The Cartosat series of satellites are LEO and limited in numbers, resulting in long revisit time. They are not sufficient to cover the vast area with better revisit times.[9] All the services need to be on a common network grid to be effectively networked and share filtered intelligence at the speed of light. India lacks common airborne data link like JTIDS due to which digital data or videos of dynamic targets cannot be shared with 'shooters' in the air. Processing and analysis of intelligence inputs from platforms, including the satellites, is done by different agencies resulting in stove piped inputs. Integrated and fused intelligence data would be much richer in quality and content. Modern airborne platforms like Rafale, Apache helicopter, and Airborne Warning and Control System (AWACS) have advanced sensors that can accurately geolocate Air Defence radars and provide optical and SAR interpreted images. There is a gap in integrating this data with other int inputs. There is growing volume of data generated from varied types of sensors, and this massive data would take months to collate and disseminate and some data may remain unutilised. Only Artificial Intelligence (AI) and Machine Learning (ML) tools would provide faster and better intelligence.

WAY FORWARD FOR INTELLIGENCE FUSION

India needs to ensure interoperability amongst various MALE and tactical UAVs of all the three services. This would be possible with common secure datalinks, standardised GES, and intelligence formats. Interoperable GES configurations would ensure access of information from any of the UAVs operating in the area. The armed forces must insist on this requirement for all future UAV procurements from India and abroad. Headquarters Integrated Defence Services (IDS) should be the central agency to ensure this.

India must ensure common airborne secure datalink for sensors and shooters to share real time data and shorten the sensor to shooter loop.

All intelligence data should be networked on a common intelligence cloud with need based authorised access.

As intelligence assets are bound to increase in future and useful int inputs would be available from modern fighters and helicopters. The most crucial requirement is to have an AI based intelligence management system which can integrate and fuse intelligence information from ISTAR, UAVs, satellites, imagery, SIGINT inputs, other visualisations and create a comprehensive and actionable intelligence data base for effective use by the armed forces. It should be able to extract relevant intelligence data as per priority defined by the commander. This software should be networked with HQ Defence Intelligence Agency (DIA), Services and Command Headquarters, Intelligence Directorates and field formations. The package should have 'change detection' capability and generate multiple layer intelligence for 'target folders'. Another advancement would be for the system to suggest target priorities for faster decision making. This open architecture system should be able to seamlessly integrate any new induction of intelligence platform. The system should have efficient and secure information distribution system to ensure efficient dissemination of intelligence to the right recipient. Such systems are operational in many Air Forces that employ multiple intelligence platforms. An example of such a system was press released by Rafael Company prior to the Paris Air Show.[10] It describes such system in greater details.

During hostilities, the intelligence assets would always be in high demand and the tempo of the operations would dictate the priority of ISR inputs. Service Headquarters should centrally control the intelligence assets during such eventualities.

Manned Unmanned Teaming assets under development by HAL, must include advanced and networked ISR capabilities to support manned fighters in future war scenarios. Their inputs would be accessed near real time by other agencies through intelligence cloud.

Data analysis and interpretation of the massive data base is crucial, especially during war when time and access to the information at the right time is crucial. Employment of AI and ML based tools and common intelligence cloud is the answer to ensure timely analysis and information dissemination. To effectively exploit stand off weapons and stay ahead of the game plan of the enemy, actionable and timely intelligence to all decision makers is an essential requirement for the armed forces. HQ IDS is the right agency to pave the way and acquire this crucial capability.

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FUSING IMINT: DRONES, MANNED ASSETS AND SATELLITES

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Abstract
Imagery Intelligence (IMINT) is one of the important intelligence collection disciplines required for preparation of an Intelligence Product for military operational planning. Due to technological evolution, there is a huge proliferation of imaging resources at various levels. The article details the evolution of IMINT and the present day IMINT functions of UAVs, drones, manned assets and satellites. The IMINT users in India and evolving IMINT needs at tactical, operational and strategic levels and Military IMINT Process are also highlighted. The IMINT fusion needs, IMINT fusion challenges and suggested ways to Achieve IMINT Fusion are then discussed. The article concludes with the way forward to include organisational changes, joint training, evolution of IMINT human resources, strengthening of IMINT sharing mechanism and integration of Drone Intelligence in IMINT matrix at all levels, underlining that effective IMINT fusion will result in economy of effort, prevention of duplication of information and discarding of unreliable inputs, which can facilitate in creation of better and reliable Intelligence Products for operational utilisation.

INTRODUCTION

Since the dawn of warfare, a commander's ability to visualise the battlefield and direct his or her forces has often meant the difference between victory and defeat.[1] Such visualisation of battlefield is possible through timely intelligence products, derived from numerous intelligence collection disciplines, to include Human Intelligence (HUMINT), IMINT, Signals Intelligence (SIGINT, which comprises of Communication Intelligence and Electronic Intelligence) and Open Source Intelligence (OSINT).[2] These days, certain new and evolving intelligence collection disciplines, such as Measurement and Signature Intelligence (MASINT), mostly used by Western Intelligence Agencies, Cyber Intelligence and Geospatial Intelligence (GEOINT) also form part of intelligence collection disciplines.

IMINT

IMINT is an intelligence collection discipline, which collects information obtained by imaging, via satellites, aerial photography through manned assets, drones and/or any similar platform. As a means of collecting intelligence, IMINT is a subset of intelligence collection management, which, in turn, is a subset of intelligence cycle management. IMINT is especially complemented by non-imaging MASINT, electro-optical and radar sensors.[3] GEOINT is the analysis and visual representation of security related activities on the earth, produced through an integration of imagery, imagery intelligence and geospatial information.[4]

EVOLUTION OF IMINT

Early attempts to capture scenes of the earth's surface consisted of observers and artists going aloft in hot air balloons. However, the true birth of IMINT came with the invention of the camera. During the American Civil War, the US Union Army used hot air balloons for observation and photography, where soldiers were sent up in balloons to gather intelligence about their surroundings. The Germans too experimented with both kites and rockets as platforms in the late 1800s. However, their early efforts met with little success. During the First World War, cameras were used on aircraft, but usually only for front line tactical applications. Rapid advances were made in both cameras and aircrafts between the wars. In the Second World War, around 80% of the intelligence gained was derived from aerial photography, which was used mainly against strategic targets such as industrial complexes, lines of communications and population centers.[5] Possibly, due to these practices, IMINT used to be earlier referred as Photo Intelligence (PHOTOINT).[6]

Having proved its worth in two World Wars, aerial photography was thereafter extensively used world over in every major conflict. During the last 30 to 35 years, the UAVs have also proved itself as a valuable IMINT tool for the tactical commanders.[7] In the recent past, IMINT has evolved rapidly to help satisfy most of the intelligence requirements. These days by allowing everyone to see the map and understand pertinent details about the enemy and terrain in time and space, the commander's and staffs' visualisation of the battlefield are enhanced.[8]

IMINT is possibly the only discipline that allows the commander to see the battlefield in real time as the operation progresses.[9] There are multiple resources to image a territory and derive intelligence out of it to prepare a significant IMINT Product for military and non military use at tactical, operational and strategic levels. The advancements in numerous manned assets, developments in the field of space, satellites, satellite imagery, proliferation of drone technology and its evolving innovative usage makes the images and videos available in real time, which if, collated, interpreted, synthesised, analysed, fused and disseminated swiftly to the users of IMINT Products in real time can facilitate a successful intelligence based warfare.

UAVs AND DRONES FOR INTELLIGENCE AND MILITARY APPLICATIONS

UAVs make significant contributions to the war fighting capability of operational forces. They greatly improve the timeliness of battlefield information, while reducing the risk of capture or loss of Manned Assets. In addition, they are cost effective and versatile systems. While Reconnaissance, Intelligence, Surveillance and Target Acquisition (RISTA) are the premier missions of UAVs, they also provide substantial support to Intelligence Preparation of the Battlefield, Situation Development, Battle Management, Battle Damage Assessment and even Rear Area Security.[10] The images and videos captured by UAV RISTA missions form a significant component of IMINT Products.

Drone technology, now less expensive and accessible, is rapidly advancing to provide more robust and advanced drones, accommodating longer flight times and heavier loads, which are being put to several military and commercial uses around the world including for operational and tactical level imaging.[11] The remote and dual-use technologies offered by drones, is essential in any conflict to address asymmetry. Ukraine has very effectively used these "homemade kamikaze drones" against Russian forces for numerous military operations including tactical imaging. In fact, Ukraine had also put out a general request for the donation of commercial drones and crowd funded for the purchase of military drones for these purposes.[12]

Some of the evolving Intelligence (including IMINT) and Military Applications of drones include the following:

- Geographic Mapping to acquire very high-resolution data and download imagery in difficult to reach locations, such as higher reaches, coastlines, islands and so on.
- Creation of 3D maps and contribution to crowd sourced mapping applications.
- Aerial photography to capture footage and its live broadcast that would otherwise require helicopters/other air assets.
- Surveillance and Reconnaissance, which is augmented by presence of thermal sensors with drones and provides them with night vision.
- Post Strike Damage Assessment.
- Drop equipment, material, food, water and supplies to difficult locations during war, before Reinforcements reach.
- After a natural or man-made disaster, drones have the capability to provide a quick close-up view of areas, gather information and navigate debris and rubble to look for injured victims. The high definition cameras, sensors and radars with drones may give rescue teams access to a higher field of view, saving the need to spend resources on manned helicopters.

Drones can drop the supplies to unreachable locations, before rescue crews reach there. They are able to discover the location of lost persons and unfortunate victims, especially in harsh conditions or challenging terrains.

- Drones may be used to monitor dangerous and unpredictable weather. Since they are cheap and unmanned, these can be sent into hurricanes and tornadoes, so that scientists and weather forecasters acquire new insights into their behaviour and trajectory. Its specialised sensors can be used to detail weather parameters, collect data and prevent mishaps.[13]

MANNED ASSETS

Manned Assets such as Aircrafts, Helicopters carry Aerial Sensors, employed to conduct both reconnaissance and surveillance missions. Reconnaissance is performed over specific targets at specific times, while surveillance is performed over typically larger areas over long periods of time. During Reconnaissance and Surveillance Missions, Tactical IMINT could be obtained from various means to include Visual, Photography, Infrared (IR), Radar and Electro-Optical (EO).[14]

Use of Aerial Photography for IMINT from manned assets offer advantages in collection of evidence across the Forward Line of Own Troops, provisioning of high resolution images to identify objects in more detail and provisioning of permanent record, which can be later used for change detection in the target area. Photo missions prove most successful when cross-cued from other intelligence disciplines. Many limitation, which apply to visual observations also apply to photograph, such as limitations caused by enemy defences, weather, darkness, masking of the target by terrain and so on, which may be reduced by careful mission planning. Timeliness is perhaps the greatest limitation of photography. Information on the imagery may have perished by the time the analyst sees it. Different sensor format (camera positions - Vertical, Oblique and Panoramic), if specified allows to see the earth's surface from different views.[15]

IR sensors detect energy that is emitted or reflected from an object. IR imaging systems detect electromagnetic waves that are outside the visual spectrum as they lie just passed visible light and just before microwaves. IMINT products obtained through IR imagery have the same properties as visible light images, as IR is near the visual spectrum and therefore it closely resembles photo images. These images are produced by recording the amount of heat released by an object onto the ground. During the day, objects absorb solar energy and release it after the sun set. Some objects release energy faster than others. IR however has a limited capability to penetrate camouflage. IR can be used during day or night, but night IR images provide better contrast. It is a passive system that does not emit signals and therefore cannot be jammed. IR imagery is degraded by severe weather and terrain and affects it the same way as conventional photo images.[16]

Imaging radar operates by emitting an electromagnetic pulse, which illuminates or paints the target area. The emitted energy after reflection from the target, gets back to the aircraft, where the signal is recorded. The amount of energy that returns and the time it takes that energy to return is calculated to produce a radar image and determine the size and location of the target. All radar imaging systems today are data linked to ground stations, therefore the information is near real time. The system uses its own energy to illuminate the target and this makes it day and night capable. The system is near all weather. Severe thunder storms degrade the image. Radar provides images of fixed targets. This is useful for terrain analysis, change detection and pattern analysis. Perhaps its greatest capability is to detect moving targets. A moving object produces a Doppler shift and is displayed as a dot on radar imagery. With the sophistication of today’s systems movers, speed and direction can be determined. The limitations of Radars are that the Resolution (impulse response) is poorer than with other systems and interpretation is more difficult and requires higher levels of training and skill. Radar is an active system that emits signals which can be jammed and is therefore susceptible to Electronic Counter Measures.[17]

EO Imagery collects imagery in the visual range using an array of detectors that sample light at fixed points. EO can be manipulated using digital techniques. The human eye can detect about 30 shades of gray. An EO system can detect 256 shades of gray. The individual pixel value of the image can be changed to identify targets that otherwise cannot be seen by the human eye.[18]

SATELLITE IMAGERY

Satellite Imagery involves obtaining photographs or the images of the Earth by Imaging Satellites. Satellite images offer numerous military applications (mostly in intelligence and warfare) and non military applications, such as in cartography, geology, meteorology, fishing, agriculture, biodiversity, conservation, forestry, landscape, regional planning and so on. Satellite Images are available in visible colours and in other spectra. There are elevation maps, usually made by radar images. Satellite Imagery is at times supplemented with aerial photography (which has higher resolution) and can be combined with vector or raster data in a GIS. Types of resolution in relation to Satellite Imagery are spatial, spectral, temporal, radiometric and geometric, which vary, depending on instrument used and altitude of the satellite's orbit. Types of images available in satellite imaging are panchromatic image (acquired by satellites, transmitted with the maximum resolution available) and the multispectral data (transmitted with coarser resolution, usually two or four times lower). At the receiver station, the panchromatic image is merged with the multispectral data to communicate more information.

SYNTHETIC APERTURE RADAR (SAR) IMAGES

SAR images can be obtained from satellites, such as RISAT. As radar images are formed by coherent interaction of transmitted microwave with the targets, it suffers from the effects of speckle noise. Special care has to be taken when interpreting SAR images, as it often requires some familiarity with the ground conditions of the areas imaged.[19]

IMINT USERS IN INDIA: CIVIL AND MILITARY

The three services are the premium IMINT users in India for their operational and intelligence purposes, closely followed by the other intelligence and security agencies. The reliance on IMINT is evolving at such fast pace that it is increasingly being adopted for innovative usage by most of the government services, to include various bodies dealing with the disaster management, forest, cartography, oceanography, conservation, geology, meteorology, agriculture, fishery, town planning and so on.

EVOLVING IMINT NEEDS AT TACTICAL, OPERATIONAL AND STRATEGIC LEVELS

With the advent of technology, world over the technical intelligence collection disciplines are increasingly gaining primacy over conventional HUMINT. Further, amongst technical intelligence collection disciplines, the ones less prone to deception have more credibility. IMINT being such discipline provides maximum evidence value to any Intelligence Product. While at the Strategic and Operational levels, the relevance of IMINT had always been at premium, the proliferation of drone technology, live feed phenomenon and nature of warfare evolving to quick and short wars have rapidly enhanced the significance of IMINT at the tactical levels of military operations. To be effective, interpreted IMINT acquired through various means needs to be collated and fused appropriately in the current intelligence product to facilitate interpretation, synthesis, analysis and dissemination and make the intelligence product valuable for military operations. This process needs to be continued during the entire cycle of operations, throughout the intelligence cycle and even subsequent to such military operation.

MILITARY IMINT PROCESS

In order to effect fusion of IMINT obtained from the above mentioned resources, it is essential that the Military IMINT Process is understood. At the strategic level, the services demand the imageries through their Intelligence and IMINT channels to DIPAC/Defence Space Agency, which based on the capability and availability, is met from the domestic or foreign (even commercial) imagery resources. Likewise, the air photos are demanded from the Indian Air Force and operation level aerial intelligence needs, such as through UAVs, Helicopters are mostly met out of the integral resources available with the services. These days availability of drones at the tactical levels provides a quick IMINT option to the commanders. Depending on the capability, resources, priority and availability, the available images are disseminated to the demanding force in near real time. The interpretation of these images occurs at various levels by dedicated Imagery Interpretation Teams and IMINT reports are disseminated across the concerned force depending on its area of operations.

FUSING IMINT

IMINT Fusion relates to congregation of all the important information from multiple images and their inclusion into smaller number of images, preferably on a single image, which may be more informative and accurate. Fusion reduces the quantity of data and constructs more appropriate and easily understandable images, by the IMINT Operatives and for machine perception. Image fusion methods are Spatial Domain Fusion and Transform Domain Fusion.

IMINT FUSION CHALLENGES

- Different IMINT software used by different agencies at various levels may not be able to talk to each other. Therefore, it may be difficult to obtain appropriate still image from video and achieve the desired fusion of video footage with the still image, mostly at operational and tactical levels, which besides difference in software, could also be due to use of different formats at various levels, lack of resources, lack of expertise and lack of time owing to operational needs and constraints. Lack of standardisation of formats and software is not peculiar to

IMINT, but to all the existing and evolving intelligence collection disciplines, however, in case of IMINT, it attains more importance as any incoherence in this system tends to complicate the IMINT Process at every functional stage of the IMINT Process. This is the most critical challenge to fusion of IMINT, as inappropriate discretion adopted by any IMINT user may complicate the IMINT Process and impede collection, analysis, dissemination of IMINT and its integration into the Intelligence Product.

- Different image fusion algorithms may be needed due to proliferation of space borne sensors. Some image processing situations need high spatial and high spectral resolution in a single image, which many available equipment may not be able to provide.
- Interpretation and fusion of huge amount of data received over a short period of time from multiple IMINT sources and agencies, especially when such data is raw and not interpreted is another serious IMINT fusion challenge. These days the heavy inflow of drone footage further complicates such fusion needs.
- There are difficulties in fusion of images obtained from various imagery means with Manned Assets. It is not really easy to fuse a photographic image with IR, Radar or EO image.
- Fusion of Air Photos of different sensor formats and camera positions is difficult due to variance in focal length and field of view. Various methods are used to calculate the height, length and distance of the object captured by the air photos. Such fusion needs detailed efforts.
- There are practical difficulties, such as different timings of the image received, which require appropriate image fusion to achieve correct IMINT timelines in multiple IMINT missions. At times, images of different resolution cause fusion bottlenecks.
- Some agencies have a tendency to share only PDF format or power point of their IMINT Product with a very little scope for the receiver to undertake any fusion at their level. There are also instances of wrongly

interpreted images shared. All these functional difficulties waste a lot of time, especially at the operational and tactical levels.

- Perhaps the most important function of IMINT is its fusion with inputs obtained from other intelligence collection disciplines, where it has an evidential value for the final Intelligence Product, which needs to be applied for the operational planning and intelligence based warfare. This is the most important feature of the Synthesis Stage of the Intelligence Cycle and should not be ignored. Tendency to rely only on IMINT for operational planning needs to be avoided.
- There have been procurement difficulties faced by some IMINT agencies, leading to supply of not the most advanced systems. Further, both civil and militarily IMINT agencies rely heavily on foreign equipment, which may create some functional discomfort, due to lack of desired support and services.

ACHIEVING IMINT FUSION

- Image fusion techniques facilitate integration of different information sources, with the fused image having complementary spatial and spectral resolution characteristics. Various commercial software solutions are available to combine images to video and extract relevant image from the video. In fact, certain advanced software provide the facility of turning photos into videos, which may facilitate appropriate fusion of videos. The difficulties faced due to lack of resources, lack of expertise at operational and tactical levels need serious considerations as during operations, an unskilled IMINT operative may prove to be the weak link, which may impose an adverse time penalty on intelligence and operational staff. The need is to have availability of optimum IMINT specialists.
- In order to harness the IMINT resources at all levels, it will be a good idea to commence IMINT Specific War Games/SATs at the tactical and operational levels in the three services to assess efficiency and generate new IMINT fusion ideas.

- Integration of IMINT specialists of civil government and commercial organisations may be made to make up any shortfall in Military IMINT resources. However, for them to be useful during war/operations, it is essential that they are suitably integrated during training, exercises and war games.
- Multi sensor data fusion could meet the more general formal solution demands of a number of application cases, as well as overcome the constraints of the instruments, which are not capable of providing such information either by design or because of observational constraints.
- Artificial Intelligence (AI) applications may be used for interpretation and fusion of a large volume of images received over a short period of time. However, for such AI Applications to be effective and efficient, optimum training of AI systems on similar images/videos is essential.
- In case more than one radar image of an area of different time periods is available, they can be combined to give a multi-temporal colour composite image of the area.[20]
- Fusion of SAR imagery with IR imagery can be achieved through pixel level fusion, feature level and decision level fusion. The Pixel level fusion is good for visualisation and suitable for homogenous sensors, but it requires sub pixel time/alignment. Feature level fusion has powerful feature vector, but it needs pixel/time alignment. Decision level fusion does not need pixel/time alignment and is suitable for heterogeneous sensor (SAR/IR), but it can be less accurate compared to a feature level. Decision level fusion therefore emerges as the best choice.[21]
- There is an inescapable need of all IMINT stake holders in the country to train together to facilitate working jointly and sort out functional level teething problems, to achieve desired fusion when needed. This is especially desirable in view of evolving IMINT technology, software resources, data management, evaluation and analysis tools and their proliferation at a very high speed.

- It is essential that the procurement process is smoothened and the Indian industry is made capable to offer indigenous IMINT equipment and provide the desired services for such equipment.

THE WAY FORWARD

- A National Level Apex IMINT Authority/Agency responsible for all IMINT functions in the country (including all civil and military IMINT functions) needs to be considered. This will help in understanding and evolving national level IMINT needs, appropriate imaging and fusion.
- For civilian IMINT personnel to understand military IMINT needs and vice versa, joint institutionalised education and training are essential. To achieve this, creation of National IMINT College needs to be considered, which may help in achieving IMINT synergy at various levels.
- The Human Resources of IMINT agencies need to evolve. Based on evolving technological and operational thresholds, certain unique talent/experts may be inducted with liberal service conditions. Amongst IMINT personnel also, there is a need to create Sub Specialists. Inter agency posting of IMINT personnel by deputations must be encouraged. This will help in proliferation of best practices amongst all IMINT stake holders.
- Strengthening of IMINT Sharing Mechanism is essential to achieve transmission of images in real time. The film must be returned to a processing site and developed before analysis is possible.
- Integration of Local Drone Intelligence in IMINT matrix at all levels is critical. The evolving importance of drones in Intelligence and IMINT functions needs to be continuously studied and desired infrastructure should be built to test and utilise their services across it.

CONCLUSION

To make our present IMINT apparatus capable of delivering the goods and becoming an effective part of a seamless organisation, fusion of IMINT obtained from various sources and agencies is essential. Effective fusion of IMINT from all resources will result in economy of effort, discarding of unreliable inputs, corroboration, effective IMINT analysis, which can facilitate in creation of better and reliable intelligence products for operation utilisation for the national security. Such IMINT fusion will be achieved better if the civil and military IMINT agencies through some reliable mechanism, achieve the highest level of integration to prevent the duplication of efforts and achieve the desired IMINT objectives.

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INTEGRATING DRONES FOR LONG RANGE PRECISION FIRES AND TIME SENSITIVE TARGETING: AN INDIAN PERSPECTIVE

Brig Devender Pandey

Abstract

Application of fire power in recent conflicts has been innovative and dynamic. 'Long Range Precision Fires' and 'Time Sensitive Targeting' with loitering drones and conventional rocket and Artillery munitions assisted by spotter drones have been extremely effective. Automated and networked integration of various fire power assets, drones, weapon locating radars, EW assets and fire control system has proved very lethal. Drones have proved their efficacy in the ISR and Targeting matrix and are being extensively employed in counter terrorism as well as conventional armed conflicts. Scope of their employment will further enhance with improvement in technology and better communication facilities.

Employment of drones for targeting and other areas in defence and security sector is inescapable. India has enormous potential to emerge as global drone manufacturing hub. The Indian Armed Forces are well poised to explore and optimally exploit potential of drones. An automated and seamlessly networked Sensor Shooter Link integrating the ISR Architecture and the Targeting Entities must be ensured. A common GIS and common communication protocol will be required to achieve the same. For enormous requirement of resources, fiscal prudence and 'Atmnirbharta' will be key factors. Training of all ranks should be given a de-novo look.

INTRODUCTION

Remotely controlled, unmanned aerial aircrafts have been in use since 1930s. The USA initially employed them for ISR missions and graduated to deploying land attack bombs and torpedoes. It started employing them in combat role during the Vietnam War.[1] After the twin tower terrorist attacks of 11 September 2001, the USA has been extensively employing armed drones across the globe for counter terrorism operations. Many high-profile terrorist leaders have been killed with precision targeting using drones. Al Qaeda leader Ayman al- Zawahiri was eliminated on 31 July 2022 in a drone attack by the USA. Two Hellfire R9X missiles fired from a MQ9 Reaper drone hit him when he was standing in the balcony at his home in downtown Kabul, Afghanistan. No one else was killed or wounded in the attack.[2] The R9X version of Hellfire Missiles have an inert warhead without any explosives. Instead, they have metal blades that kill the target without much damage to surroundings. Earlier, targeted killing of General Qasem Soleimani, Iran's most powerful military commander,[3] in a precision drone attack by the US Forces on 03 January 2020, highlighted how the battlefield has become extremely transparent and extended beyond boundaries. Efficacy of the drone attack was demonstrated by annihilating the target near a busy civil airport without any collateral damage.

Employment of drones for conventional operations have also increased exponentially. In recent conflicts, employment of fire power has been remarkably innovative and dynamic. Long range precision targeting with loitering drones as well as conventional rocket and Artillery munitions assisted by spotter drones has been extremely effective. In the ongoing Russia Ukraine War, both countries are employing drones of all kinds to complement the conventional weapons.[4] Earlier, in Nagorno-Karabakh conflict between Azerbaijan and Armenia, the Azerbaijan forces used Turkish supplied drones to devastating effects. The Armenian tanks, guns, troops and equipment suffered heavy casualties.[5] In Turkey-Syria conflict of early March 2020, Turkish Forces adopted the same methodology of 'drone strikes and massed Artillery fires' destroying more than 100 armoured vehicles and killing hundreds of Syrian forces. This Turkish offensive was largely carried out leveraging Drone Artillery spotters and Electronic Warfare capabilities.[6] This article attempts to analyse the current and near future trends in 'Targeting', highlight importance of 'integrating drones for long range precision fires and time sensitive targeting' and draw certain imperatives for the Indian Armed Forces.

FUTURE OPERATING ENVIRONMENT AND BATTLEFIELD MILIEU

In coming decades, factors like population growth, continuing globalisation, migration, rapid urbanisation, rapidly changing technologies, requirement of energy, water, oil, competition for resources and climate changes are likely to pose significant challenges in the strategic context.[7] The emerging conflicts' environment is characterised by complexity, chaos and competition. Amidst all this, 'Gray Zones'- spaces between outright war and peace, have emerged where diverse types and numbers of actors compete for resources, access, territory, and power within states and across them.[8]

The Joint Doctrine of the Indian Armed Forces 2017 identifies the character of future wars to be ambiguous, uncertain, short, swift, lethal, intense, precise, non-linear, unrestricted, unpredictable and hybrid.[9] The future battlefield may be characterised by intense engagements; nonlinear battles; simultaneity of operations; increased battlefield transparency; synergised and orchestrated employment of fire power resources and employment of precision and high lethality weapon systems in a hybrid warfare environment and may be under the overall backdrop of a nuclear, biological and chemical warfare threat.[10]

Over the past few years, almost all the military thinkers, analysts and commentators have assessed the future wars to be "short and swift". Though some contrary views; cogently arguing that "in reality the chances of a successful, short and swift war are minimal and future wars will be long with heavy political consequences" have also emerged.[11] The ongoing Russia Ukraine war seems to be justifying this thought process.

With these characteristics, the future military operations are likely to be across multi domain. Generally, land, sea, air, space and cyber are assessed to be the domains where competitions are going on and future conflicts might take place. But as the warfare is evolves, new domains will keep getting added. Summarising the modern warfighting, Lt Gen Raj Shukla (Retd), in a tweet dated 28 July 2023, identified eight domains - land, sea, air, subsea, seabed, EM, space, cyber and three matrices - range, speed and precision to deliver combat over match, aided by new talent pipelines, innovation and civil – military fusion. Elaborating further, he classified 'submarines' and 'seabed sensors' as different domains.[12]

Whatever be the 'dynamics of the warfare', 'operating environment' and 'future battlefield', the Armed Forces must adapt, develop capabilities, train and be fully prepared for all eventualities. Drones and unmanned systems have emerged as an important and potent tool for conduct of Warfare and counter terrorism operations.

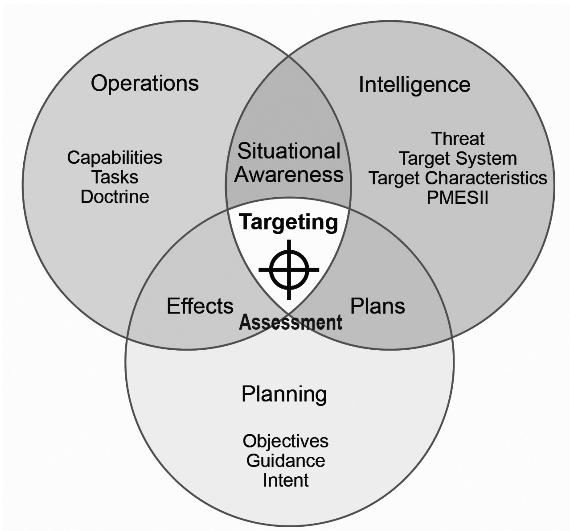
TARGET, TARGET ACQUISITION AND TARGETING - AN OVERVIEW

The US Armed Forces' Joint Publication 3-60, 'Joint Targeting' has formally defined 'Target' and 'Targeting'. "A 'Target' is an entity (person, place, or thing) considered for possible engagement or action to alter or neutralise the function it performs for the adversary. It must be consistent with national strategic direction and selected to accomplish the assigned missions. It can be a facility, individual(s), virtual, equipment or system's capability."[13]

For operational planning purposes, targets are categorised as 'planned targets' and 'targets of opportunities'. A high-value target (HVT) is defined as a target that the enemy can least afford to lose or that provides him with the greatest advantage. A high-payoff target (HPT), is that which must be acquired and engaged to achieve success of the friendly forces. Some special types of HPTs having very high importance to mission accomplishment are termed as 'time-sensitive' and 'component-critical' targets.[14]

'Target Acquisition' is the process to locate a target with desired degree of accuracy required by the designated weapon systems to destroy or suppress it effectively.

"'Targeting' systematically analyses and prioritises targets and matches appropriate lethal and nonlethal actions to create specific desired effects to achieve the objectives. It links intelligence, operations and plans across all levels of command and phases of operations. The purpose of 'Targeting' is to integrate and synchronise fires into joint operations by utilising available capabilities to generate a specific lethal or nonlethal effect on a target."[15] The targeting overview is depicted below:



PMESII - Political, Military, Economic, Social, Information and Infrastructure

Targeting Overview[16]

Source: Google Image

The publication further elaborates, "Targeting encompasses many processes, all linked and logically guided by the joint targeting cycle that continuously seek to analyse, identify, develop, validate, assess, and prioritise targets for engagement. Targeting process is categorised as 'deliberate' and 'dynamic'."[17]

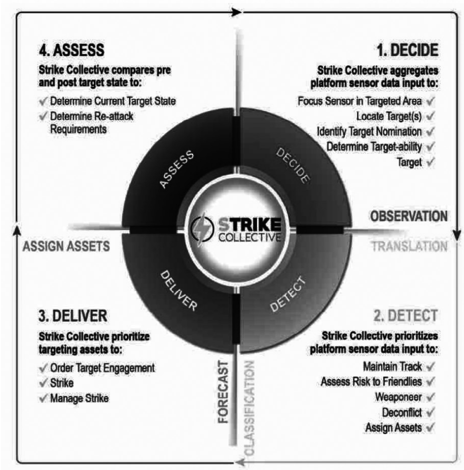
Joint Targeting Cycle[18]

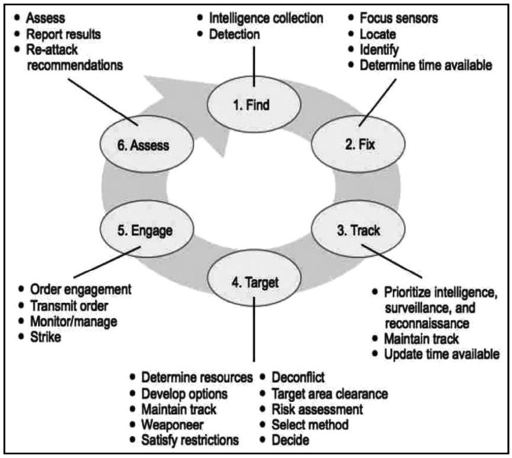
Source: Google Image

Correlation of ISR and Targeting also needs to be highlighted. ISR is the process of integrating the intelligence cycle with surveillance, target acquisition and recce tasks in order to enhance the commander's decision-making capability and facilitate the targeting process. ISR operations focus on production of information and intelligence required by the decision makers. Drones are one of the most important resources in this ISR and Targeting matrix. They have provided enormous flexibility and tremendous advantage to military planners.

TARGETING PROCESS

There are a number of targeting processes that various Armies have adopted to engage enemy targets. One such process is - decide, detect, deliver and assess (D^3A) process.[19] Another process is 'find, fix, track, target, engage and assess' (F^2T^2EA) process. Generally related to dynamic targeting, the F^2T^2EA process is also referred as 'kill chain'.[20]





D^3A Targeting Process F^2T^2EA Targeting Process

Source: Google Image

EMERGING TRENDS IN TARGETING-EXTENSIVE EMPLOYMENT OF DRONES

In recent conflicts involving Russia-Ukraine, Turkey-Syria, Armenia-Azerbaijan and Libya; capabilities of various weapon systems have been on display. Certain very interesting trends have emerged in ISR and Targeting. Automated and networked integration of various firepower assets, drones, weapon locating radars, EW assets and fire control system have proved to be a very lethal combination. Drones have played the most important role in this 'ISR and Targeting Cycle'. They are being employed for various combat roles like intelligence gathering, surveillance, target acquisition, jamming the communication and attack with loitering munitions as well as for supporting logistics.

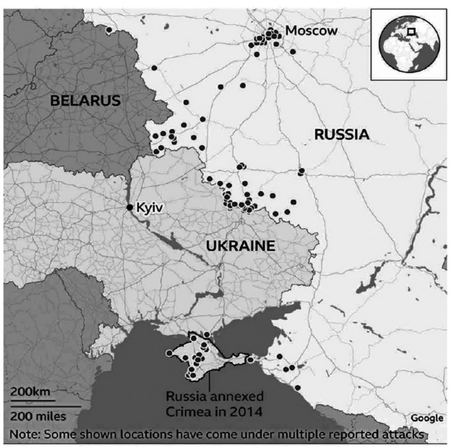
Russia-Ukraine War. The ongoing Russia Ukraine war is witnessing extensive employment of drones by both the belligerent countries. According to a report published on 19 May 2023 by the Royal United Services Institute (RUSI), a British think tank specialising in defence issues, "the Ukrainian military is now losing some 10,000 drones a month on the battlefield, or more than 300 a day". In the beginning of the war large-scale tactical

UAVs, like the Turkish Bayraktar TB2, were being employed by Ukraine to attack Russian tanks columns. However, now mainly smaller UAVs, often of civilian origin are being employed.[21] Though many commentators have questioned this claim but the importance that drones have been accorded is not to be missed.

As per another report in the Washington Post, drones have been integrated into every phase of fighting by both countries, with extensive fleets, Air Defence and jamming systems.[22] Apart from employment in combat role by two sides, drones are also being used by journalists to collect information and reporting from otherwise inaccessible war zones.[23] Some analysts have assessed that in April 2022, Russian flagship 'Moskova' was sunk by Ukraine, innovatively employing drones. Probably, the ship's defences were diverted by the Turkish make 'Bayraktar' drone and then Neptune anti-ship missile was used to attack the ship and destroy it.[24]

According to Russian media reports monitored by BBC Verify, more than 120 suspected drone attacks have taken place this year in Russia and Russian-controlled territory in Ukraine. Oil facilities, airfields and energy infrastructure have all been targeted.[25]

Reported drone attacks on Russian targets



Source: BBC research (data from 1 January to 1 August 2023).

Turkey's Lethal Fire Assault decimating Syrian Forces in the Battle of Idlib in March 2020 has brought Artillery integrated with UAVs and cyber assets for EW, to renewed prominence in 21st century military operations. Turkey reportedly jammed the Syrian radars, acquired the targets using the UAVs and delivered a deadly fire assault with guns and rockets. As spotters for Artillery, the UAVs are filling in a risky role that used to be performed by slow-flying observation planes for directing accurate Artillery fires.[26]

Russian Concept of Reconnaissance - Strike and Recce - Fire System. This innovative and integrated employment of UAVs for target acquisition, cyber-attacks followed by a lethal fire assault of rockets and Artillery was first demonstrated by the Russians against the Ukrainian forces in July 2014 in "Zelonopillya Rocket Attack."[27] As per a report in 'The Washington Post', "a single Russian Artillery 'fire strike' destroyed almost two Ukrainian mechanised battalions, in a few minutes."[28] It was an innovative and audacious employment of firepower integrating EW assets, UAVs, and firepower assets like rockets and guns.

Russia traditionally has been the biggest proponent of the 'firepower supremacy'. As per the Global Firepower 2023 data, it has the largest Artillery in the World.[29] Russia undertook a massive modernisation drive of its firepower resources as well as its concepts of application. To counter NATO Forces' air superiority, it invested heavily in precision guided missiles like Iskander and Kinzhal and advanced Artillery weapon systems like the 2S35 Koalitsiya 155 mm self-propelled howitzer and the 9A53 Uragan M1 multiple rocket launchers. Simultaneously, considerable efforts were put in for development of the drones and the UAVs. For Artillery, special targets potter drones with approximate ranges of about 40 Km were designed. The modern T14 Armata tanks are fitted with tethered target acquisition drones. A UAV company equipped with drones like Eleron, Granat and Orlan has been grouped with each mobile brigade.[30]

Analysing the Russian Artillery modernisation, Roger N McDermott, a Senior Fellow in Eurasian Military Studies, The Jamestown Foundation, Washington DC, highlighted that, the Russian weapon systems like Artillery and precision missiles receive target information from the UAVs and other forward-spotters, transmitted in real time through the Strelets intelligence management and communications system. This facilitates high precision fires in a very short time. The UAVs are integral part of the divisions of heavy duty Artillery and help in precise aiming at the target. ROS, the Russian variant of network centric warfare, aims to integrate all units and subunits operating in the battlefield. To ensure the speed and continuity of the fire impact on the enemy, 'Reconnaissance-Strike' and 'Reconnaissance-Fire complexes' are being created.[31]

The Russian Armed Forces conducted a strategic command staff exercise, Tsentr 2019. Extensive use of UAVs in combat operations was probably the most important aspect exercised in it. The Exercise witnessed independent use of drones for reconnaissance,identification and designation of the targets for strike by aviation and field Artillery. The usage of drones and UAVs in conjunction with field Artillery is a critical element of Russia's Reconnaissance-Fire System, greatly enhancing speed of action and accuracy in fire control.[32]

Israel Defence Forces (IDF) have also given lot of emphasis on integrating firepower from various air, sea and landbased platforms, interconnected through a single C4I network. The Artillery corps is responsible to destroy the fixed targets as well as targets of opportunity. The distinct advantage with the landbased launchers and other infrastructure is that, once connected, they all are relatively simple. Here again, the drones and UAVs play important role in targeting methodology. In addition to increasingly precise and longer-range missiles and munitions, the Artillery corps is operating UAVs.[33]

It is abundantly clear that drones will be an important component of the ISR Targeting Architecture. They have amply demonstrated their efficacy in recent conflicts. Scope of their employment will further enhance with improvement in technology specially AI and better communication facilities.

IMPERATIVES FOR THE INDIAN ARMED FORCES AND RECOMMENDATIONS

Relevance and importance of drones, not only for Defence but various other sectors like Industry, Infrastructure, Agriculture, Logistics, Supply Chain Management, Retail, Communication, Journalism, Mass Media and many other fields have been well understood by all stakeholders. It has been identified as a niche technology and a core area of research and development for Atmnirbhar Bharat. A conducive policy ecosystem is being created with Drone Regulations 3.0. Industry needs and public safety concerns are being balanced by the Indian Government. This will give a boost to India's fast developing drone industry.

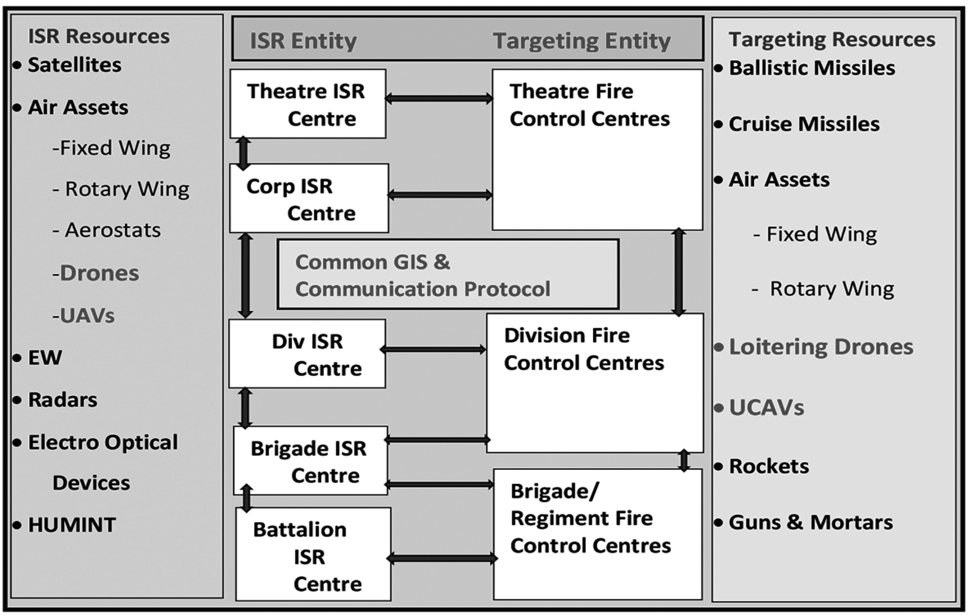
In a report titled, "Making India the Drone Hub of the World", Federation of Indian Chambers of Commerce & Industry (FICCI) in collaboration with Ernst & Young (E&Y) has estimated that, by 2025, the global drone market is likely to be of US$ 54 Billion. For India, the drone manufacturing potential could be worth US$ 4.2 Billion by 2025 and grow to US$ 23 Billion by 2030. The Nation has the potential and the opportunity to emerge as a drone hub on the global stage.[34] Considerable efforts are being put in by all to exploit this opportunity.

Indian Armed Forces are on a cusp of transformation. Modernisation and transformation of the three Services are being given impetus. With the polity and the bureaucracy on board and a CDS in place, things seem to be set for integration of the three Services. It is a matter of time when the Joint Theatre Commands will be in place. Though; it will just be a beginning of the transformation. Lots of ground has to be covered for being a lean, mean, agile and a modern force.

Indian Armed Forces have correctly appreciated the potential of drones and are well poised to exploit it. Effective liaison must be maintained with Industry and all other stakeholders involved in research and development and subsequent mass production of drones.

Integration of drones for 'Long Range Precision Fires' and 'Time Sensitive Targeting' is amply demonstrated by the Armed Forces of various countries in the ongoing conflicts as well as exercises. Employment of drones for the same by the Indian Armed Forces, as well, is inescapable. The framework to enable it will require considerable resources, efforts and coordination at all levels. Certain recommendations to streamline the same are elaborated below:

- Emphasis in the Indian Armed Forces has generally been on the ISR ops. The aspect of '**Joint Targeting**' must also be incorporated at every level.
- To ensure effective, real or near real time target engagement, an automated, networked and seamless **Sensor Shooter Link** will have to be established. Integration of the ISR Architectures and Targeting Fire Control Entities at all levels is a must. A **common GIS** and **common communication protocol** ensuring seamless connectivity across all the three Services as well as other entities having stakes in the National Security is a foremost requirement for this.



Networked ISR – Targeting Architecture

- Importance of satellites for ISR has been amply demonstrated by the US private company, Planet Lab. Founded by three former NASA engineers in 2010, it now operates the largest private satellite constellation of the Earth observation satellites.[35] It has been commercially supplying satellite images across the globe. India must consider its own constellation of low earth orbit small satellites for continuous surveillance and reconnaissance. It will boost the Armed Forces' C4I2SR capabilities thereby strengthening the sensor-shooter link. It will also improve the connectivity and data transmission between ground stations, air-borne assets and space.[36]
- The Battlefield Surveillance System (**BSS**) must be fielded on priority. The system has made very good progress over the years. Once fielded, further improvements desired by the users can be incorporated, subsequently. Its integration with Targeting Entities should be ensured on priority.
- Firepower resources must have their own integral, automated and networked observation and target acquisition systems. **Drones, UAVs and RPAS must be incorporated in the overall ISR and Targeting matrix**.
- Requirement of resources for an automated and networked ISR - Targeting Architecture including drones is likely to be enormous. It can only be met with **Indigenisation**. **Fiscal prudence** and **Atmnirbharta** will be key factors.
- With data automation, inventory management has become easy and **Theatre or terrain specific equipment** might be a better idea.
- **Training** of all ranks including Strategic and Op Leaders will need a de-novo look. Technical threshold of the soldiers will have to be enhanced.

CONCLUSION

The future battlefield will be unpredictable. The nature of warfare is dynamic and will keep changing continuously. Drones will have a very important role and wide employability in Defence and Security Sector. In the recent conflicts, drones have proved their efficacy for the kinetic as well as non-kinetic operations. India has the potential to be a global drone manufacturing hub in near future. The Defence Forces must exploit this opportunity optimally.

The Indian Armed Forces will have to be fully prepared for any eventuality. 'Targeting' must be approached in a holistic manner. Drones must be integrated for 'ISR and Targeting' as well as other areas like logistics and communication. Networking the battle space, strengthening the ISR grid, integrating the Firepower assets with drones and fire control systems will be key battle winning factors in future.

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186-207

DRONES AS FORCE MULTIPLIERS

Gp Capt Amitabh Mathur (Retd)

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

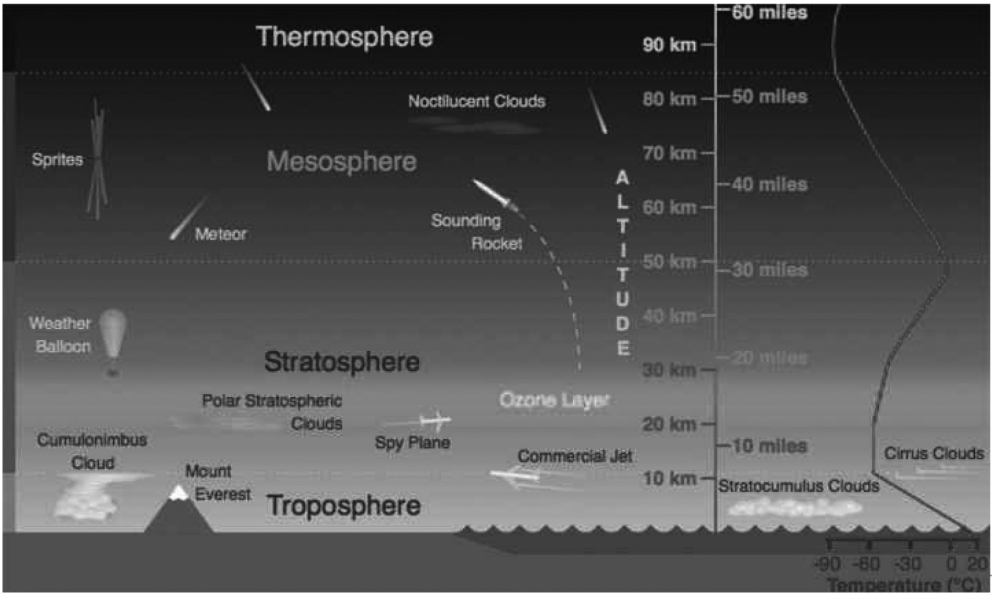
bandwidth and because communications are often jammed. The work must be done "on the edge," meaning within the drone. Many of Ukraine's drones have "fairly rudimentary AI capability" aboard. Small, low-powered chips can work out whether an object below is a T-72 or a T-90 tank, a job that could once 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

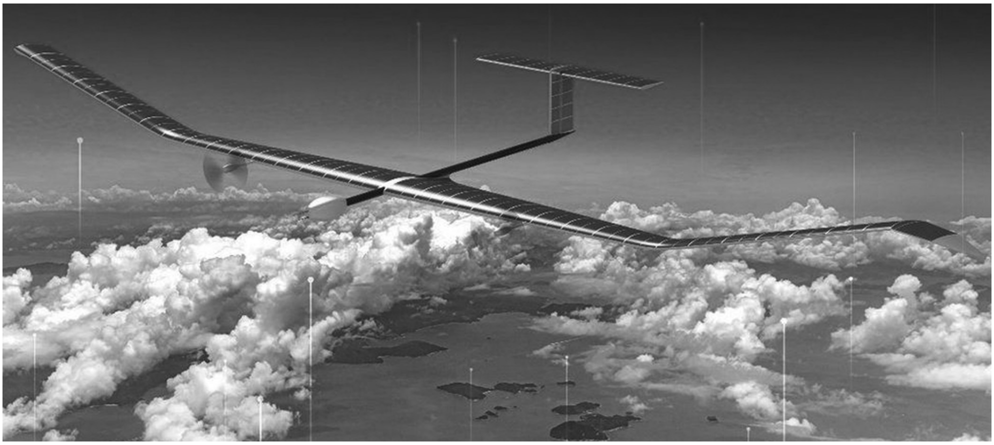
HAPS are Autonomous systems that include a fleet of craft (i.e., one or more uncrewed vehicles) and the systems that manage them. **The Near Space**, usually defined as the range of Earth altitudes from 20 km to the Kármán line[13] at 100 km from the surface of the Earth, has attracted worldwide attention 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]



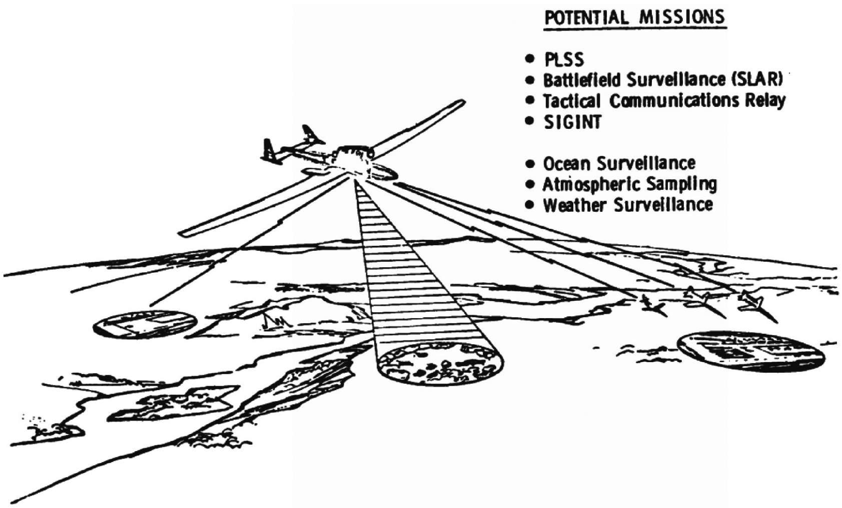
Source: Airbus.

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.

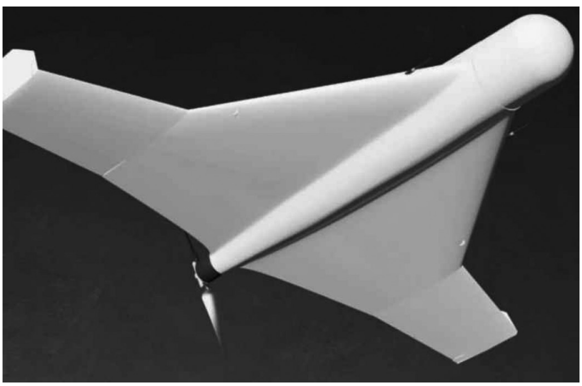
Finally, the conflict has proved that intelligence alone is not enough; it must also be used properly. Therefore, the software will track in real-time using satellite and drone imagery and visual recognition algorithms and target the adversary with unprecedented speed and precision. The software can 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

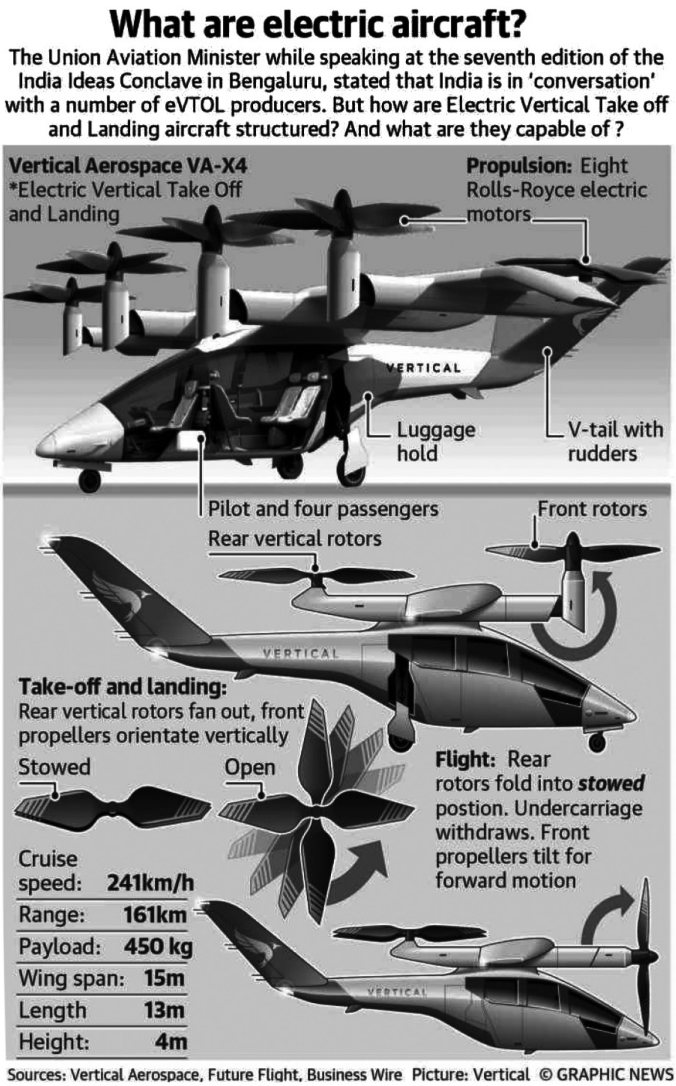
The advent of swarm drones allows each drone to operate independently to inflict damage without exposing the crew to risks. Military forces can use swarming drones in three ways: to attack, defend, and provide support functions such as intelligence, surveillance, and reconnaissance.[29] Unlike true swarms, 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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DRONES AS FORCE-MULTIPLIER IN FUTURE WARS

Brig (Dr) Navjot Singh Bedi (Retd)

"War is the continuation of policy with other means".[1]

The rationale for waging a war by a nation is to ultimately to achieve its political ends and has been the practice since ancient times. Over the years, only reasons for waging wars and the method by which wars are to be waged have undergone a change. Long ago,wars were fought adhering to codified rules and practices which were adhered to. To quote few such rules / practices; fighting used to be waged only between sunrise and sunset, civilians, women, elderly and children were not to be targeted and fighting was carried out amongst adversaries of equal strength / abilities (for e.g. during Mahabharata, a Maharathi or a great warrior used to only fight against a Maharathi) and those without a weapon were not targeted.

As is the case with all things, over a period of time, dilution crept in these rules ; night attacks previously frowned upon were now acceptable with women, civilians & elderly also open to being at the end of adversaries ire. It was possibly felt that if enough civilians were killed and adequate civilian infrastructure was destroyed, there would be no one to run the production lines / factories & these could not function.

INTRODUCTION

In WW II, use of Air Power became a prominent battle winning factor. The carpet bombing carried out by Germany over UK during the Battle of

Britain and the air raid carried out by the Allies on Berlin, during World War 2 are classic examples of this. Though killing civilians and damaging infrastructure demoralizes the country and thus it affects a nation's ability to wage war, yet it has its associated moral dilemmas. The asymmetrical exploitation, adaptation & innovative use of military drones or cheaper and smaller commercial drones, by an entity against critical assets and armament platforms of a conventionally stronger adversary, has addressed this paradox. Thus now unintended collatoral damage is avoided, yet the adversary is adequately hurt and results provided in a more economical manner.

Critical technologies that have a civil & military use are prone to proliferation and this has speeded up not only the development but also the exploitation of military drones. In the Nagorno-Karabakh war (2020) **UCAVs** were used by Azerbaijan & they are also being used in the Russian Special Military Offensive in Ukraine, which is another inflection point in these rules.

As policies and rules for waging war change, armies also need to adapt themselves. In order to be battle worthy, armed forces need to modernize constantly. ***There is thus a need to optimally manage this change in the ways in which war is likely to be fought****, in order to* minimize collateral damage while employing military power. This is where drones have created a niche for themselves as will be explained in the subsequent paragraphs

FEW DRIVERS OF CHANGE

Certain drivers of change in the way wars will be fought in times to come will be **Economy, Public Opinion, Impact of Emerging Technologies &Punitive Cost of a Nuclear Strike** which incidentally are also in consonance with the ISO primary drivers of change[2] which are Economy, Society (akin to Public Opinion), Technology and Environment (which would be affected due to a nuclear strike). The emphasis on economic development and the prohibitive costs associated with wars makes the likelihood of a full-scale war & collateral damage due to unfettered freedom to use Air Power extremely remote in the present day context (the ongoing Russia –Ukraine war being an aberration). Under the overhang of nuclear weapons, war is a no win situation because the possibility of total global annihilation cannot be wished away. No government relishes the prospect of its soldiers dying in combat and being answerable to the public for the same, as public opinion matters. Lastly, many technological developments have revolutionised the way wars will be fought. This is nowhere more apparent than in the case of use of drones to assist warfighting.

Post WW-II, a large number of conflicts have primarily been "low intensity" conflicts,[3] as these were proxy wars which were fought within a specified region. These conflicts were though fought using conventional weapons, yet these were combined with tactics used in asymmetric warfare coupled with use of high technology weapon platforms. Drones have a major role to play in this field, from being used as weapon/surveillance platforms to modes of transportation for arms/ammunition/drugs and counterfeit currency. The impact of each of these four factors, with regards to employment of drones, has been analysed in subsequent paragraphs.

Economical Factors

A full scale war brings in its wake shortages of food, petroleum, water, clothes, potable drinking water, medicines and habitat. Due to the prohibitive costs involved, for developing nations like ours, a conventional full scale war can at best be fought for ten to 15 days, before the pressure from the international community builds up. The subsequent costs and efforts of reconstruction and rehabilitation are colossal, as is being seen in Afghanistan, Iraq and Syria. So the philosophy of classical full scale war involving carpet bombing style of degradation by air needs a rethink. Drones thus not only provide a cheaper, precision targeting and less manpower intensive alternative for waging warfare to the attacker but also minimise the prohibitive costs of collateral damage to the adversary.

Public Opinion

No democratically elected government would like to receive body bags of its soldiers killed in combat and people also do not take kindly to news of civilians/women/elderly/children being targeted. One of the major reasons for the defeat of US forces in Vietnam was that they lost the propaganda war at home! When US soldiers returned home, they were called 'Baby Killers" and the US soldiers lost the will to fight. In modern times, collateral damage (even of the adversary) is not acceptable, hence the need to look at other options to wage wars. The need of the hour is two-fold; to devise ways in which wars may be fought without physical involvement of troops and to reduce collateral damage to the adversary. This is possible by use of precision strikes using smart munitions delivered through unmanned weapon platforms or drones like 'Searcher' & 'Herons'. Drones can never replace the conventional assets of the armed forces like manned fighter aircraft, tanks and artillery but are effective force multipliers.

Nuclear Deterrence

Due to the availability of nuclear weapons with a large number of nations, a classical war is actually not an option as it is a no win situation for all concerned because the possibility of Armageddon always exists. Hence there is a need to find other smarter means of waging war, which though does not bring the world to a nuclear precipice, yet achieves the desired end result. This void is filled up by "low intensity" skirmishes/conflicts.[4] These regional conflicts are in a way proxy wars, which are fought within local regional geographical areas, using "conventional weapons," combined with asymmetric warfare tactics. Thus again we can consider precision strikes, unmanned weapon platforms (ground, ariel and marine based), smart weapons & ammunitions and robots duly aided with artificial intelligence and drones.

IMPACT OF MODERN ICT ON DRONES

Emerging modern ICT are innovations which represent **significant developments** within a field to enable credible advantage.[5] Technological growth however is of two types i.e. ***incremental or disruptive.*** Those technologies where a new method replaces the previous technology and make it redundant are called Disruptive technologies. However **Incremental development builds upon the previous technology.** An example of the latter is the semi-automatic rifles, which were built upon bolt action rifles, which were an improvement upon the earlier flint lock and muzzle fed rifles. Drones is another example of incremental development having disruptive payoffs.

Analysts like Martin Ford argue that *"as information technology advances, machines and software begin to match and exceed the capability of workers to perform most routine jobs,"*[6] even in the realm of military. Drones are one such field where unmanned vehicle platforms enable mass surveillance, eavesdropping, security, anti- piracy ops, border patrol, hunt fugitives etc. They can also be used in carrying out an armed attack from an aerial platform. Their utility in search & rescue missions, especially in inaccessible locations is immense. Disposal of explosives & bombs is another imaginative utilisation of UAVs. Besides this, drones can enhance the efficacy of military raids and also provide a virtual presence in urban streets in an urban setting. Listed below are few other currently emerging technologies, including advances & innovations in various fields their possible military applications, especially in drones:

Emerging Technology	Perceived / Potential Military Application
Screen less display[7] (To include retinal display on a virtual screen, contact lens which are Bionic & Tapping a device fixed to Eye)	AR/VR, By tapping a device fixed to Eye, the wearer can reference various blue prints, in a 3 Dimensional manner; for e.g. those of a construction yard. Head mounted display & adaptive optics for next generation soldier which can give command to/ receive a feed from drones.
Flexible electronics[8, 9]	Electronic devices that are flexible & can be folded (like tablets, projection screens, smart-phones etc). Solar cells which are flexible yet lightweight can be rolled up for deployment. These help reduce the All Up Weight of drones.

Memristor[10, 11]	These can be used in electronics which are smaller yet faster. These consume lower power & are analogue storage devices & also in AI. These can help give enhanced capability & longer range to drones.
Bio-fuels[12]	These are apt for storage of energy especially in case of long range transportation requirements.
4G/5G Cellular Communications	Pervasive computing. LTE networks. Creating intelligent devices. Ideal for drones especially when operating in swarm configuration
Machine vision[13]	These can be used in controlling various processes and in Biometrics; for example in guidance of an autonomous vehicle). Also used in visual surveillance & where there is a need for human to interact with a computer for egrobot vision. Ideally suited for drone
Quantum computing[14, 15]	Enhanced computing speeds for situations which need a reduced OODA loop for quick decision making. Suited for sending commands to/receiving data from drones.
Quantum cryptography[16]	Secure communications. A force multiplier for drones.
Radio-frequency Identification[17, 18, 19]	This will especially be relevant if drones are operating in a swarm mode & in a hostile Air Defence environment.
Anti-matter weapon	This with Directed energy weapon, Electro -laser, EM weapons & Particle beam will be weapons for next generation warfare. Ideally suited to be mounted on drones. Can also be effectively used against drones.
Molecular nano-technology, nanorobotics	Machines can make anything given the materials. Drone fabrication made easier, lighter and more economical.
Swarm Robotics[20]	The intelligence potential of a swarm of robots is enhanced. Robots may also function in autonomous mode. Nano robotics is another potential use case as is operation of robots in a swarm. The behaviour of robots can also be controlled. Especially relevant for drones operating in swarm mode.

Scramjet[21, 22]	Hypersonic aircraft. May be used to enhance speed of drones if propulsion can be remotely controlled.
High Altitude Platforms	Communications. Orbiting drones may be used to as a relay platform to provide communication
Cloak of invisibility[23, 24]	Camouflage, cloaking microscope tips at optical frequencies. An invisible drone would be a tremendous force multiplier.

DRONES IN FUTURE CONVENTIONAL WARFARE

Conventional wars with massed armies supported by Air Dominance or total Air Superiority is a thing of the past. Future wars are more likely to be primarily Network Centric Wars (NCW),[25] with small task oriented forces/mission oriented teams to put boots on ground when and where required, **duly facilitated by a favourable air situation, over the desired area of operations.** NCW uses the advantage provided by information into a tactical advantage. This is achieved by networking of forces which are geographically dispersed.[26] NCW[27] operates on the premise that a 'system' is comprised of many interlinked smaller/sub systems. This is feasible with drones, especially when operating in a Swarm mode.

Future wars will see a predominance of sensors and unmanned platforms (both aerial, terrestrial and marine), which will be guided on to undertake precision strikes/operations, based on specific intelligence, supported by a multi-layered communication network, with built in redundancy. Human presence will be relegated to the background, controlling the operations from network control centres. Troops will be sent in to carry out the mopping up once the bulk of the opposition has been obliterated. **Ground forces and drones are also likely to be employed to carry out surgical operations/ precision strikes respectively, based on specific intelligence**. The idea of employing drones to carry out a "*Balakot type of precision air strike*" and for effective aerial border patrol with deterrence capability has immense potential and is pregnant with immense possibilities, especially in the backdrop of India likely to acquire MQ-9B HALE drones.

TASKS AND ROLES FOR DRONES IN PEACETIME AND IN WAR

Drones perform a variety of tasks throughout the world. These include Intelligence gathering, Surveillance and also Reconnaissance. Communication, Air Support & neutralisation of enemy air defences can also be assigned to drones. Target Acquisition, Post -Strike Battle Damage Assessment, Mine Detection & an aerial Radio Relay post are few other ways in which drones can be used. They can also be used as target drones, for Tactical Reconnaissance and for Correction of Artillery fire. Drones like the Hunter and Predator can carry weapons if modified to do so. UAVs can also be used as aerial Observation posts, for Surveillance of Maritime boundaries and for Border Security. Global Hawk is an example of a strategic reconnaissance high-altitude UAV.

The employment of drones is limited only by imagination. The Arab Israel war in 1973 & the Bekaa Valley battle of 1982 saw Israel using UAVs to deceive enemy SAM radars. This it did by using UAVs to simulate aircraft. Missiles were launched at the UAVs by many SAM sites. This enabled the attack aircraft to home on to these SAM sites and destroy them.

DRONES vs MANNED AIRCRAFT

In environments which are contested and where command & control may be a constraint, manned aircraft is preferred. This is because such situations entail greater autonomy in decision making. A UAV however has advantage of having no risk of fatal casualty or of being captured as it has no aircrew. Moreover the range and endurance of UAV is considerably more. Drones, like manned aircraft have also now evolved to be used for specific purposes like Air Interdiction or Reconnaissance or Air Defence etc. To perform different functions, the payload of UAV is changed and the same UCAV can be used in Peacetime or War, depending upon its payload.

DYNAMICS OF ESCALATION CONTROL OF A DRONE

A standard drone is controlled by a Ground Control Station (GCS). In a few cases (like in case of Predator UAV), till the UAV takes off, the control is with a pilot who mans a local LOS ground station through a satellite. After take-off, the control is handed to a second pilot who is sitting in a ground station, at a Command Post, which is at another location, geographically displaced. The satellite link is used to fly the UAV mission in this way. Then for landing, control is again given back to a local station on ground. During normal peace time use, the standard procedure i.e. control by a local line-of-sight GCS could be used. This control, during times of hostilities/war could be escalated to the control through a Command Post, at another geographically displaced location, with adequate oversight.

ETHICAL AND MORAL ASPECTS OF EMPLOYMENT OF DRONES

Firstly, employment of drones for kinetic action in areas with population may cause extensive collateral damage and civilian casualties, which can be avoided by specific intelligence and precision targeting. Secondly, at times valuable intelligence may be lost when 'Seek & Destroy' type of strike mission is executed by drones. This is because it leads to elimination of the terrorist on the spot thus foreclosing the option of intelligence that one might have been able to obtain had the terrorist been captured alive. Then is the issue of Reliability of Drones'. Reportedly,crashes of the Predator drone, purely due to mechanical reasons/error, was 43 times for every 100,000 flying hours, against 02 for a typical manned aircraft crash. Last issue is whether elimination of suspected individuals is justifiable either legal grounds or on ethical issues. Though as a fallout of the 9/11 attacks, a law had been passed by the US government which enabled the President of US to use military force, if required, to pursue those who are perceived to be responsible, yet world over the jury is still out on this issue.

CONTRADICTORY VIEWS ON NCW & ITS EFFECT ON EFFICACY OF DRONES

Gen Raduege Jr, Director, DISA, said that U.S. troops in Operation OIF, "the weapon platforms used were essentially the same as those which were used in Operation Desert Storm; the only difference being that the effectiveness of those used later in Op OIF had been considerably increased"[28] However over dependence on NCW is fraught with its own hazards as has been amply brought out by Charles Perrow, in his talk[29] on Information Assurance, delivered in NDU, in May 2003 said; "*Our incipient NCW plans may suffer defeat by [adversaries] using primitive but cagey techniques, inspired by an ideology we can neither match nor understand; or by an enemy who can knock out our vulnerable Global Positioning System or use electromagnetic pulse weapons on a limited scale, removing intelligence as we have construed it and have come to depend upon. Fighting forces accustomed to relying upon down links for information and commands would have little to fall back upon*."

Also, since NCW dwells on dissemination of information, thus the effect of misleading or misinterpreted data which may entering the system needs to be guarded against. This spurious data can enter either through deception by the enemy or by a genuine error. This is where drones will actually be tested because unlike piloted aircraft, where a highly trained pilot is making decisions based on inputs and analysing the same with his experience and gut feeling, the drone has to rely on AI, GPS coordinates and the ability of a pilot sitting at a remote location.

PROBLEM AREAS IN EMPLOYMENT OF DRONES ESPECIALLY IN HYBRID WARFARE

Though the future of conventional/non-conventional wars are likely to be shaped by extensive use of drones, duly enabled by latest tactics and technology, yet certain areas where we need to tread with caution, while adopting this approach are as listed below:-

- In the future battle field, each piece of mobile equipment as also personnel are potential sources of RF emissions. Thus, it is a herculean task to coordinate the use of frequency spectrum in a battle space. Due to the dependence of drones on data, command and PNT links, this is likely to increase in future as there will be conflicting demands from commercial telecom operators on the scarce spectrum resource. This will be even more prominent whenever drones are expected to operate in swarm mode. Moreover EW is a very successful counter-measure and is the Achilles heel of drones.

- When operating in areas where the GPS coverage is weak, the accuracy of locational awareness is limited. It can however be overcome by fusion of positional data which is obtained from diverse number & type of sensors. In the absence of this, drones are not likely to be successful as they can be easily steered off course due to jamming/spoofing of signals, as GPS can be controlled by adversaries.
- Besides kinetic means, drones can also be targeted by lasers and high power microwave weapons. Thus future drones need to be built with some basic inherent capabilities to ward off these threats. This will in turn increase their All Up Weight, thus impacting the payload/range/cost. It is thus a trade-off between survivability, lethality, economy, complexity and capability.
- Transferring information between networks which have diverse levels of classification as regards security,is difficult. Successful key management for encryption, especially with mobile systems is a challenge. This gets compounded with the as drones need to be deployment speedily. Also, as a response to rapidly evolving situations in the battle zone, various military units/teams need to be reconfigured in quick time. Thus human intervention is required to facilitate correct and cogent decision-making regarding the nature of data which can be transferred. This can however be facilitated by security systems which are multi-layered.
- The successful use of drones like the Reaper had earlier been restricted to benign AD environments like Afghanistan, Iraq & Central Africa. Azerbaijan however used drones extensively during the Nagorno-Karabakh war in 2020 and they have also been used by both sides in the ongoing Russian Special Operation in Ukraine. The survivability of a drone in a contested air space has thus only recently been battle evaluated, post their use in active hostile environment. It has been seen that despite their losses, drones can support and even augment air power, land forces

and maritime assets because there are innovative ways in which the kill-chains of drones can be operationalised.

- Drones are however plagued by certain limitations. They are constrained by terrain, inclement weather, limitations of power, limited payload and average speed. However, their biggest asset is their cheap cost as because if one uses sophisticated and costly missiles to neutralise cheap drones, it is not an economically viable option for the defender.

CONCLUSION

Vice Admiral A. K. Cebrowski (Retd), U.S. Navy had said:

> *"At the turn of a millennium we are driven to a new era in warfare. Society has changed*[30] *and the underlying economics and technologies have changed. Now fundamental changes are affecting the very character of war. We are in the midst of a revolution in military affairs (RMA)."*

The scenario is changing dynamically and to survive in such a scenario, it's important to make strategic choices. Attrition bombing by conventional Air Force planes and massed tank columns yields decreasing returns on investment (as was seen due to the efficacy of Ukrainian tank hunting teams), reversals are possible, threat of loss of life is there and at times the outcome could be in doubt. In comparison, the RoI (Return on Investment) provided by drones is increasing, with the increase in fluidity of operations. This drastically shortens the OODA loop and effectively denies the adversary the option to adopt an alternate strategies, thus enabling success.

Massed military and commercial drones have augmented multi-domain combat capabilities & have contributed to successful offence and defence. Though the attrition of drones in contested battle zones might be high, yet their reduced costs and low risks of commercial drones (which can be repurposed), makes them an attractive option to be there in the arsenal of all militaries as well with various non state actors. Likewise it will be wise to also have in place countermeasures (especially EW measures) for drones.

Such an approach in terms of their military reforms is needed because recent advances in technology allow the US and other developed nations to engage in warfare half a world away; the drones are launched from Afghanistan but guided from the USA. In order to usher in a change, we must take a conscious decision as regards putting in the intellectual capital and earmarking requisite financial resources, as also putting in place processes and a mechanism for sufficient indigenous capacity in this field.

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NAVAL DRONES: FORCE MULTIPLIERS IN MARITIME OPERATIONS

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INTRODUCTION

It is a well-known dictum that "*there are no runners up in war*." The nature of warfare in the context of this unforgiving truism has per-force, been transformative; wherein the singular aim has been to win at all costs. Therefore, the warring parties often resorted to innovative means and out-of-box innovations to surprise the adversary with regard to their Force's strength and intent. The advent of the industrial revolution and the consequent development of technology changed the nature of warfare forever. As technology matured and its benefits in gaining asymmetrical advantage over the adversary became apparent, technology started becoming the main driver for formulating the strategy of warfare.

Various technological applications of warfare did surprise the adversary when they progressively appeared on the scene for the first time. Two centuries down the line, the nature of warfare has now evolved into an era of high-technology enabled disruptive weapon systems and platforms, where in vigorous technological innovations to ensure surprise to the adversary – and consequently ensure victory – is the norm. The multi-domain unmanned systems – in air, land, sea-surface and underwater – are one among many such high-technology means of warfare.

This article covers unmanned systems in the maritime surface and under-sea domain only. Thus, the envisaged operational roles of unmanned surface vessels (USVs) and the unmanned underwater vehicles (UUVs) in pre-conflict, and conflict scenarios have been discussed in detail. Their potential as force-multiplier during warfare when they are used in innovative ways, has also been investigated. The status of their development and operational usage in India has also been dwelt upon, followed by the recommended roadmap for their optimalutilisation to engender effective maritime security in the proximate Indian Ocean region, in future.

ENVISAGED OPERATIONAL ROLE OF NAVAL UNMANNED SYSTEMS

The use of naval unmanned systems – which includes USVs and UUVs/ submersibles – has seen accelerated expansion since the start of the new millennium, wherein these systems are progressively becoming an integral part of modern-day warfare, both, in traditional and non-traditional domains. In fact, unmanned systems have become the preferred option for many missions which may either be highly repetitive, requiring longer sustenance or pose unacceptable risks to the attendant crew. Their use in a hostile environment – besides being cost effective – is also seen as less escalatory when compared to usage of other conventional military hardware or platforms.

The preference of policymakers and operational commanders to utilise unmanned systems has increased steadily with the growing capabilities of these systems to augment or supplant human beings in conduct of various operations. In areas protected by mines or threatened by integrated air defense systems (IADS) where operational planners would like to minimize the risk to human lives, unmanned systems will certainly provide a viable alternative.

Such unmanned systems would be particularly useful for conducting operations in environments containing nuclear, biological, chemical, or radiological contamination. For instance, after the 2011 Fukushima nuclear disaster in Japan, robots were used to conduct on-site survey of the facility after the calamity when it was reckoned to be too dangerous for human exposure.[1] Subsequently, if such unmanned systems become irreversibly contaminated, and the cost/effort involved in decontaminating them is considered to be too high/unacceptable, then they can be easily abandoned without significant losses.

Some other scenarios which have not been fully explored yet, may pose significant physical and mental problems to the human body during sustained operations. Unmanned systems can greatly mitigate many of them. Some obvious examples relate to undertaking high gravity force maneuvers, operating at very high altitudes, sustaining great pressures at depth, or remaining submerged for long periods of time. Humans require life sustaining systems in these environments, which add size, weight, and complexity to current manned vehicles. The unmanned systems will clearly obviate the need for all these requirements.

Besides the risk to human lives, unmanned systems also offer advantages of consistent performance and effectiveness for monotonous missions such as long-term, persistent surveillance. It is challenging for humans to spend hours conducting surveillance and maintain the same level of awareness and attention to detail. The algorithms in associated computers/processing systems can be programmed to detect patterns and unexpected anomalies, and present them for further review by human analysts, thus aiding in informed decision-making.

As the diversity of tasks has increased, types of unmanned systems have also proliferated. These systems come in all shapes, sizes, forms and configurations, and are generally built as per role and mission specifications. They can either be configured for standalone single mission or a combination of one or more roles. The specific operational missions of the USVs and UUVs will be covered separately in undermentioned sections – though there are certain commonalities in these roles because of their inherently unmanned nature and the associated advantages and limitations.

UNMANNED SURFACE VEHICLES (USVS) – OPERATIONAL MISSIONS AND ROLES

Some missions and roles in conventional warfare where USVs can prove to be great force-multipliers – and which have been listed as per role priority accorded by the UN Navy's USV Master Plan of 2007 – are mentioned below:[2]

- Mine Countermeasures (MCM)
- Anti-Submarine Warfare (ASW)
- Maritime Security (MS)
- Surface Warfare (SUW)
- Special Operations Forces (SOF) Support
- Electronic Warfare (EW)
- Maritime Interdiction Operations (MIO) Support

Mine Countermeasure Role

The main aim of MCM is to provide a safe transit passage for a large number of fleet ships, including high-value assets like aircraft carrier formations and amphibious forces. This requirement consequently translates into sanitisation of a large sea area, particularly at entry/exit routes to the harbours and in restricted navigation areas and narrow channels/choke points. In order to fulfil this objective without damage to one's own assets and crew, the USVs – as also the UUVs working separately or in tandem – will play a vital role as MCM entails the conduct of these 'dirty, dull and dangerous'[3] tasks. They provide long time-on-task, which allows sustained mine hunting and sweeping cover at huge cost saving and risk reduction; thus increasing the effectiveness of dedicated MCM ships.

The MCM USVs will be provide the Force Commander with the capability to conduct comprehensive MCM ranging from intelligence collection about mined waters to first response MCM at safe stand-off ranges, thus enabling effective conduct of subsequent fleet operations. The intelligence about mined waters also provides the option to the Force Commander to bypass the dangerous area altogether, if there is a chance to do so. MCM operations by USVs will open transit lanes for forced entry missions, clear operating areas for naval forces, and enable protection for amphibious forces, keeping manned forces clear of danger,all the while. In addition to the above advantages, actual force multiplication effect generated by the use of USVs in MCM role comes by the way of lesser time taken for safe passage and access to the contested area; as also confident execution of the operational plan.

Anti-Submarine Warfare (ASW) Role

Increasing submarine threat from potential adversaries – particularly in tropical waters – calls for establishing and maintaining an effective and credible ASW capability. It is also a given that there will never be enough manned assets to cover a large area associated with either defending approaches to harbours and other shallow waters; or sanitising the carrier strike group/expeditionary amphibious forces operating and transiting areas against submarine threat.

USVs offer significant force multiplication for ASW operations because they can perform the ASW mission at some level of autonomy. This enables the manned combatants to become free of this task and thus be employed for other more pressing operational tasks. USVs in ASW role also provide an additional layer of defense-in-depth for the manned surface group; as also reduce risks to the manned platforms that would otherwise have been conducting the ASW mission themselves. In any case, USVs can serve as off board sensors, thereby extending the range of detection and sanitization effect without increasing risk. The manned mother ship functions as the control and coordination centre for numerous USVs, thus providing the economy of effort while enhancing decision-making inputs. The US Navy envisages the undermentioned concept of operations for exploitation of USVs in ASW role:[4]

- employment of non-lethal weaponry by USVs
- employment of lethal weaponry by USVs
- accumulation of intelligence information on threat submarines by USVs

- USVs engaging in diversionary maneuvers to create a deterrent or distracting effect against threat enemy submarines

Maritime Security Role

Maritime Security role consists of securing ports, harbour approaches and navigational channels;and protecting ship and maritime infrastructure (piers, docks, anchorages, warehouses) from a wide spectrum of threats ranging from conventional attack to special operations to specifically targeted terrorist attacks. Generation of comprehensive Maritime domain awareness (MDA) plays a major part in implementation of effective maritime security. A list of maritime security tasks for which the USVs can be employed is as follows:[5]

- Strategic and tactical intelligence collection: Signal, Electronic, Imagery (SIGINT, ELINT, IMINT)
- Chemical, Biological, Nuclear, Radiological, and Explosive (CBNRE) detection and localisation
- Harbour and Near-shore monitoring
- Deployment and monitoring of expendable surveillance sensors/ arrays
- Specialised mapping and object detection and localisation
- Non-lethal and lethal threat deterrence
- Monitoring boat traffic in rivers/inland waterways for personnel, contraband or weapons smuggling, and other illegal activities

Surface Warfare Role

Surface Warfare capability for USVs is quite similar to some aspects of maritime security role mentioned earlier, but also incorporates the engagement of more difficult threats further offshore as well as in high seas. Such USVs have to have a larger hull, be capable of doing higher speeds (30-40 knots), be equipped with MDA and ‘identification friend or foe’ (IFF) wherewithal, and be armed with role-specific armament payload. These USVs can carry out Coastal/Homeland Security/Port Security Patrol, support special force operations and also engage hostile targets – in modes either remotely controlled by an operator, or semi-autonomously, or fully autonomously.

Special Operations Forces (SOF) Support Role

The aim of SOF is to achieve disruption by 'hit and run' to achieve asymmetrical advantage using surprise as the main element, rather than traditional 'force on force' kind of warfare. SOF units require support for conducting missions involving unconventional warfare, counter-terrorism, reconnaissance, and direct action, clandestine missions in enemy held territory etc. The USVs can support such SOF activities by way of Intelligence, Surveillance and Reconnaissance (ISR)[6] using standard or non-standard sensors, and by providing transportation and material support. Innovativeness to enhance stealth and ensure non-attributability of blame would play a great role in form, size, design and features of such USVs.

Electronic Warfare Role

USVs have broad role in application of naval and joint campaigns to support conventional warfare, irregular warfare and internal security through strategic use of electronic warfare and Information Operations. This capability is used in synergy with the Maritime Security (MS)mission. The best part is that the USVs can be programmed to always engage in this activity in a secondary role also, while they continue to perform their primary tasks. The USVs, suitably equipped with an Electro-Optical/ Infrared(EO/IR) sensor on a retractable/extendable mast,can be used as picket ships ahead of, or on flanks of the carrier formation or expeditionary group, to conduct passive signal detection and threat warning for the battle group. Provision of chaff launchers or jammers on such USVs or even additional dedicated ones, will enable them to be used for anti-missile defence as well.

Maritime Interdiction Operations (MIO) Support Role

Activities by naval forces to divert, disrupt, delay, or destroy the enemy's military potential before it can be effectively brought to bear against own forces, generally fall under the ambit of MIO. This implies that MIO by default, is a manned mission. The intended role of USVs is to support this manned mission by way of increased domain awareness in the area of relevance. This requirement would entail the deployment of a small USV that can precede a boarding party by investigating the target vessel above and below the waterline. For this role, its payload would likely include ISR, EO/IR, CBRNE and Weapons of Mass Destruction (WMD) detectors, and possibly even, remotely operated vehicles (ROVs), UUVs, and UAVs.

UNMANNED UNDERWATER VEHICLES (UUVS) – OPERATIONAL MISSIONS AND ROLES

The US Navy defines an unmanned underwater vehicle as "*a Self-propelled submersible whose operation is either fully autonomous (pre-programmed or real-time adaptive mission control) or under minimal supervisory control; and is untethered except, possibly, for data links such as a fiber optic cable*."[7] By this definition, the UUVs are expected to possess certain unique operational advantages related to autonomy, risk reduction, low profile, flexibility of deployment, adaptability, and persistence. These features would enable them to deploy or retrieve devices at/from the seabed and water column; gather, transmit, or act on all types of information in the undersea realm; and engage targets lying above and below sea surface, at sea bottom; orin the air, and even on land.

While the operational roles envisaged for the USVs have been explained above, there are certain commonalities with those stipulated for the UUVs too, the minor difference being in the operating realm – the former operating on the sea surface, and the latter, underwater. The US Navy's UUV Master Plan of 2004 lists the following roles for its UUVs in the order of priority:[8]

- Intelligence, Surveillance, and Reconnaissance
- Mine Countermeasures

- Anti-Submarine Warfare
- Inspection/Identification
- Oceanography
- Communication/Navigation Network Node
- Payload Delivery
- Information Operations
- Time Critical Strikes

Intelligence, Surveillance, and Reconnaissance (ISR) Role

The envisaged ISR roles for UUVs are generally consistent with the 'maritime security' role in respect of the USVs,[9] the only difference being in their domains of operation. Their unique features enable them to undertake these activities at long standoff distances, operate in shallow waters, work autonomously, and provide a level of clandestine capability which is not available on other systems. UUVs can increase the intelligence collection extent of manned platforms into inaccessible or disputed areas without endangering high value assets and their crew; and achieve force-multiplication effect by raising the number and density of sensors in the undersea battle space.

Mine Countermeasure Role

There is great similarity between the MCM roles of USVs explained in the earlier section, as well as those of UUVs. In fact, the UUVs in many cases, can be used by the USVs as supporting equipment to carry out underwater reconnaissance of mined areas (detection, classification, identification, localisation), sweeping/clearance of floating, moored and seabed mines (neutralization, breaching) and protection operations against mines (Spoofing, jamming). The real utility of UUVs however, lies in time-stamped collection of oceanographic data in peace time, wherein collated data on currents, waves, bathymetry, water visibility, seabed physical parameters, seaweed density, sand bars, etc. can be used to highlight pattern inconsistencies and facilitate change detection to determine mineable areas; and mine-like objects.

Anti-Submarine Warfare Role

The role similarity between USVs – as mentioned in earlier section – and UUVs extends to the ASW realm also. The added advantage is in their clandestine modus-operandi, which can be best leveraged when they operate close to enemy harbours, narrow channels and choke points. They can also act as mobile mines if required and so tasked; wherein they can independently detect a target, navigate towards it, and collide with it below the waterline in self-destruct mode.

Inspection/ Identification Role

As part of port defence and Force protection architecture, the infrastructure like jetties, moorings, piers, drydock gates, as also the hulls of docked ships and 'port operations support' vessels are required to be regularly inspected against terrorist and sabotage threats. Since the areas in question are large, substantial amount of manpower and effort would be required to achieve their foolproof sanitisation. Instead, these tasks – including identification of dangerous objects like depth charges, limpet mines and other underwater ordnance and their disposal – can be carried out from safe standoff ranges by deploying UUVs. The UUVs thus provide an alternate option to conduct multiple, rapid hull and other underwater structures in a cost-effective fashion; thereby sparing the divers and support staff for more complex tasks requiring real-time human intervention.

Oceanography

UUVs are the best suited equipment for carrying out critical tasks like collection of hydrographic, oceanographic, and meteorological data in all sea states and conditions. By implication, they become a great force multiplier to manned platforms in provision of near real time data to the tactical commander at sea at required frequency and locational comprehensiveness, as aid to decision making. When used in conjunction with remote sensors, other ocean data, and models; UUV-acquired data provides combat units with critically required advance knowledge of environmental parameters such as bathymetry, tides, waves, currents, acoustic propagation characteristics, locations of navigational hazards, and other objects of interest.

Undersea Communication/ Navigation Networking Role

The UUVs can provide undersea communication and navigation relay function for a wide variety of platforms. As a communications relay, the primary task would involve the provision of connectivity to static underwater sensors, chains or systems. UUVs, because of their mobility, can establish links with underwater stations and other surface platforms and even space-based systems. The obvious advantages of using UUVs in submerged communications role include extended standoff distances and greater accessibility to remote areas. Potential users of this facility would include other UUVs, submarines, Special Forces units, and other recipients where clandestine communication is desirable.

Payload Delivery Role

Payload delivery is not a task per-se; but is required in support of many underwater missions like MCM, ASW, Oceanography, Support for special operations, and time critical strikes. The UUVs in this role, would simply become a means of underwater transportation; and will provide the energy, navigation, autonomy, and payload deployment systems which may be needed to accomplish those missions. The size and endurance of such UUVs will naturally depend on the weight of the payload and the distance to which it is required to be transported.

Information Operations (IO) Role

The UUVs' capability to operate clandestinely in shallow waters and areas too hazardous for a manned platform to operate in, makes them the ideal platform for IO missions – aimed at deceiving, deterring and disrupting the adversary. The UUVs appear to be most suitable for two IO roles, viz., as communications/computer node jammers, and as submarine decoys.

Time Critical Strikes (TCS)

The US Navy considers the TCS as one of the lowest priority missions for UUVs, because an autonomous weapon launch capability is still regarded as unethical and controversial. Till such time, human control of weapon launch will be the norm, this capability will probably be kept on hold in foreseeable future. However, there is no denying that UUVs can provide low-risk, high-payoff strike mission results, providing an ability to clandestinely deliver weapons closest to the adversary's vital assets/vital points, in extremely compressed time frame.

INNOVATIVE EMPLOYMENT OF USVS AND UUVS IN SUPPORT OF NAVAL OPERATIONS

The different roles and methods in which the USVs and UUVs can be operationally utilised, have been discussed in the earlier section. The combination of one or more features or roles of these unmanned systems in innovative ways can deliver asymmetrically high outcomes in the most cost-effective manner with minimum economy of effort. Certain advanced applications of these unmanned systems are also being conceptualised. Though some such applications are being tested at demonstration or 'proof of concept' stage in the US, the Chinese technologists are also working on these ideas. While there is no limit to the innovative usage potential of unmanned systems, some known applications currently under preliminary development are discussed in brief in the succeeding paragraphs.

Innovative Usage of USVs

The USVs can be utilised in many innovative ways. Armed mini- or micro-USVs can be used to swarm a large warship or a target of interest. The two known ways in which China intends to use the USVs to gain tactical advantage over the adversary relate to their use as swarms around the high-value assets of the opposing force; and for coastal assault by incorporating amphibious characteristics to the USVs for use, both at sea and on land.[10]

In an innovative display of USV employment, a Chinese company demonstrated coordinated formation manoeuvres by 56 mini USVs – called 'shark swarm' – sometime in 2018, a video of which was released by *Global Times* on 31 May 2018.[11] The mini USVs, moving at high speeds, formed various patterns, shapes and Chinese characters, without colliding with each other. They also formed the shape of an aircraft carrier, while another larger unmanned boat waded directly into the formation, imitating the take-off of a fighter aircraft from the notional carrier's flight deck.[12] The military potential of such USVs moving in large numbers at high speed to overwhelm the adversary warship's defences, by swarming all around it, are more than obvious. The Chinese private Industries' plans to collaborate with the defense industry to further develop USVs and related devices for reconnaissance, command, attack and other sea battle functions were reflected in one such statement to the effect that "*Unmanned swarm boats can be used with high efficiency in escorting, mine sweeping, intelligence gathering and amphibious operations.*"[13]

China also claims to have successfully tested the World's first armed amphibious USV on 08 April 2019. The USV, named Marine Lizard (Hai Xiyi), is 12 m long, has a trimaran hull; and is propelled by a diesel-powered hydrojet, enabling 50 knots speed. When approaching land, the USV can release four track units from under its hull which find traction to climb the beach. The amphibious USV can reportedly sail autonomously, avoid obstacles and plan routes with the help of indigenous Beidou satellite navigation network. The amphibious USV is also capable of integrated operations with other units in the theatre.[14]

China has been conducting trials of a large unmanned cargo ship named '*Jindouyun*' since 2017. The prototype USV carried out its first trial cargo delivery run in December 2019, wherein its networked and distributed control systems and cyber-physical algorithms, enabled the Cargo USV to carry out autonomous navigation, track management, obstacle avoidance, and controlled berthing, sailing and other decision-making functions.[15] Since, Chinese maritime administrators are exploring the feasibility of commercial operation of these cargo USVs in the transport, supply and marine sectors in due consultation with the IMO,[16] it is not entirely inconceivable that such ships can be programmed for rogue behaviour to possibly collide with the adversary's warships in narrow channels, restricted waters or choke points. While such 'incidents' may possibly be explained away as having occurred on account of technological malfunction; the diabolical plan of putting that combat unit of the adversary out of action for some duration at the minimum, would have been achieved.

Innovative Usage of UUVs

The most innovative use of UUVs is in the form of Extra-large UUVs (XLUUVs), wherein there is an ongoing effort to manufacture as large a UUV as is possible, and equip it with as many capabilities as feasible vis-à-vis manned submarines. In the absence of human element, advanced artificial intelligence algorithms would control their autonomous navigation, collision avoidance, depth keeping, and combat mission suite.

The US, as the foremost technologically advanced nation is running the '*ORCA*' research and development project, wherein five prototype XLUUVs based on Boeing's 'Echo Voyager' are being developed for operational use in combat, alongside the US Navy manned ships and submarines. While the details of '*ORCA*' project are classified, Boeing's 'Echo Voyager's' dimensions – 51 feet long with rectangular cross section of 8.5X8.5 feet, weight about 50 tons – provide an indicative assumption of its size. The 'Echo Voyager' XLUUV can attach an additional modular 34 feet long payload, increasing its final length to as 85 feet. The US Navy reportedly commenced the underwater testing of '*ORCA*' XLUUV on 04 April 2023.[17]

China, considering itself as the technological peer competitor of the US, has developed its own XLUUV named 'HSU-001'; and unveiled it for the first time during its National Day military parade on 01 October 2019.[18] While details of its capabilities and dimensions are not yet available, maritime analysts believe that such vessels can carry smaller UUVs, mines or torpedoes. They can possibly be carried to deployment locations on board regular submarines, warships, landing ships or even large helicopters, and thereafter deployed for wide-ranging tasks associated with manned submarines. Given the nature of undersea warfare, stealth, autonomy, and scope of operational tasks which are beyond the capabilities of manned submarines/submersibles; these XLUUVs will indeed prove to be huge force multipliers during futuristic warfare.

STATUS OF DEVELOPMENT OF USVS IN INDIA

Though the Indian Navy has been using radio controlled target boat (RCTB) since 1990s for practice firing by ships' guns, the boats have been imported from abroad. The boats measuring about 7 meters long, displacing about 2 Tons, capable of cruising at 15-20 knots with maximum speed of 35 knots and controllable from 20-25 km away, provide a high-speed maneuvering target for realistic surface action firing practice by ships. These boats which continued to be used after life extensions were sought to be repaired through open tender bidding by Naval Dockyard, Mumbai in 2016.[19]

The Indian Navy's Directorate of Indigenisation has sought to develop remote controlled target boat (RCTB) – amongst a list of other products – through private industry participation, as laid down in its Indian Naval Indigenisation Plan (2015-2030) document.[20] While the document is quite aspirational, not much is known about the actual progress on the ground. Some expectations about the production of a USV in India were raised, when a model of Seagull USV was presented by Elbit Systems of Israel to the Garden Reach Shipbuilders & Engineers (GRSE) during Def-Expo 2018. The attendant insinuation was that the two firms will jointly build this USV.[21] For the record, Seagull is a 12 meter long USV that can be operated from a mother ship or shore station. It provides multi-mission capabilities including ASW, MCM, EW, maritime security and underwater commercial missions.[22]

It is quite apparent from the above discussion that research and development on USVs in India is at a very nascent conceptual stage only; and whatever little is available in service, is all imported. The need for indigenisation is now being articulated in the 2030 time frame.

STATUS OF DEVELOPMENT OF UUVS IN INDIA

Research and development scenario in India, in respect of UUVs is far better USVs. The Defence Research and Development Organisation (DRDO) is currently designing and building multiple types of Autonomous Underwater Vehicles (AUVs) – under generic category of UUVs – to meet naval requirements. These range from small slow-speed vehicles to military-class, free-flooding ones weighing up to 1.7 tons. These are meant for various maritime security roles like surveillance and mine counter measures in ports/harbours, coastal waters, as well as in deep seas.[23]

One such vehicle is the 4-meter long, 1.4 meter wide, flat-fish AUV, designed for the Indian Navy. It can travel at about 4 Knots (7 kmph) and dive up to 300 meters depth. Weighing about 1500 kg, the AUV has two interconnected cylindrical pressure hulls. The robotic vehicle is fully pre-programmed – in terms of algorithms and mission requirements – and is piloted by an onboard computer. Since the thrusters are inside the pressure hulls, it is externally vibration free.[24] The Indian Navy, apparently satisfied with its trial performance and potential for future operational usage, ordered 10 such systems.[25] Figure 1 below shows a representative picture of the flatbed AUV.

Figure 1: Flatbed AUV: Representative Picture

Source: India Defence Blogspot

The Central Mechanical Engineering Research Institute (CMERI), Ranchi, has also developed and patented a UUV named AUV-150. This UUV, built in active collaboration with DRDO, is 4.9 meter long with half meter diameter; and is capable of seabed mapping, coastal surveillance, mine counter-measures oceanographic measurements, surveying and underwater photographic inspection. It is capable of both,RF and acoustic communication; and is role stabilised for better mission performance, even during rough weather. Its slight positive buoyancy enables better diving control, and prevents it from getting lost at sea in case of malfunction.[26] Figure 2 below shows a picture of AUV-150.

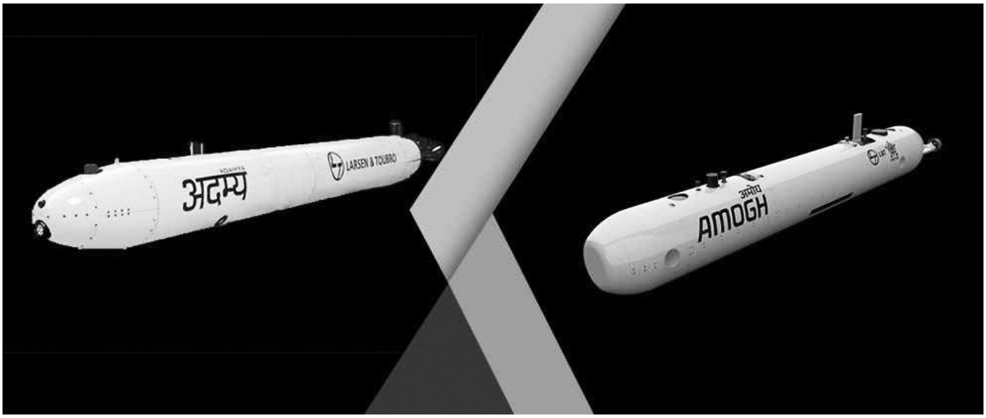
Figure 2: AUV-150

Source: CMERI.

UUV Development by Private Sector

M/S Larsen and Toubro Defence have also carried out design and development of a series of AUVs for the Indian Navy. These include 'Adamya', 'Amogh' and 'Maya' AUVs. A representative picture of 'Adamya' and 'Amogh' AUVs is shown at Figure 3.

Figure 3: 'Adamya' and 'Amogh' AUVs: Representative Picture



Source: L&T Defence

'*Adamya*' can be launched from the torpedo tube of a submarine. It is 5825 mm long with 533 mm diameter, and weighs 1012 kg. The AUV with contra-rotating propellers, has endurance of 8 hours, can operate up to depth of 500 meters, and has maximum speed of 6 knots. It can carry different payloads depending upon mission requirements. '*Amogh*' AUV is a third generation AUV, developed in collaboration with M/S Edgelab, Italy. It is designed for hydrographic and underwater surveillance. It measures 5700 mm long with 700 mm diameter, and weighs 1000 kg. The AUV has an endurance of 22 hours, can operate up to depth of 1000 meters, and has maximum speed of 5 knots. "*Maya*' is a small and modular AUV capable of carrying scientific and commercial payloads up to 4 kg till 200-metre depth. It is 1742 mm long with 234 mm diameter, and weighs 55 kg. The AUV has maximum speed of 3 knots, and endurance of 8 hours. It can be used for undersea inspection, and as an expendable underwater Target.[27]

RECOMMENDED WAY AHEAD

The maritime threat quotient for India from both, traditional as well as non-traditional sources has been on the increase. Ever-increasing Chinese naval footprint in the Indian Ocean Region – particularly since commencement of the Gulf of Aden anti-piracy escort task in 2008 – clearly indicates that China will be permanently present in India's primary areas of maritime interest. Pakistan's concept of operations against India, as mentioned in its first ever maritime Doctrine of 2018 articulated an *"approach of provocative and flexible mobility using sea space …"* and to *"… hit first with maximum effects and minimum application of force."*[28] The 26/11 Mumbai attacks by State-supported terror group, have enlarged the scope of maritime based threats to India's security, like never before.

Since it is a given that every mile of India's maritime zones can not be sanitised by manned platforms on a continuous basis; it is imperative to use technology and its applications to undertake major portion of this task – which is indeed being implemented too. The USVs and UUVs, with their inherent operational advantages with respect to autonomy, human safety, stealth and accessibility; thus, have a major role to play in the Indian maritime security architecture. The US has been using its sail-drone USVs for continuous surveillance in and around the Strait of Hormuz to ensure safety of its ships as well as security of this vital global energy SLOC. The US Navy has created an altogether new 'Task Force-59' under its Bahrain-based Central Command to integrate the unmanned systems with its manned fleet ships, and regularly conducts manned-unmanned teaming exercises to validate the concept for use in future wars.[29]

While India has not been able to leverage the USV technology to indigenously develop unmanned boats, the track record of DRDO – particularly its Visakhapatnam-based Naval Science and Technological Laboratory (NSTL) – in designing and prototyping UUVs has been quite remarkable. Therefore, this existing indigenous research, development, design and manufacturing base must be rapidly leveraged towards operationally viable military products. The Indian Navy's *Swavlamban* Document released by the defence minister Shri Rajnath Singh in August 2020 has also exhorted the Indian industry to design, and develop naval hardware including remote control target USVs, and special purpose UUVs under' Make' category of defence Procurement Procedure 2016.[30]

However, it is posited that while it is all very well to lay out requirements, conceptualise indigenisation, develop specialised technology base, produce prototypes,and successfully test technology demonstrators in many cases; the maritime security of the nation continues to be at risk all the while from broad spectrum of threats in the neighbourhood, as mentioned above. Therefore, the crying need of the hour is to push certain technologies in mission mode, with all the research establishments, scientific community,academia, public and private sector industries, national security policy makers, as well as the ultimate users, contributing to the same cause.

The final aim of course, must be to get operationally usable products in the hands of the users. The development and manufacture of USVs and UUVs, should surely find itself on top of this critical 'must have' technology, for all the operational roles that these platforms can engage in – as explained in detail earlier in this article – for achieving asymmetric advantage over the adversary.

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DRONES AND BORDER MANAGEMENT: THREATS, CHALLENGES AND OPPORTUNITIES

Gp Capt (Dr) Swaim Prakash Singh

INTRODUCTION

Among the many utilities of drones, border management is where drones hold significant potential as a transformative technology. Effective border management is essential for national security in a country as vast and diverse as India. It can be utilised in protecting against unauthorised crossings, smuggling, and other threats. Drones provide enhanced surveillance, rapid response, and cost-effectiveness in monitoring and securing the nation's borders, thereby enhancing security measures. Drones are equipped with sophisticated sensors, cameras, and communication systems, allowing them to collect real-time data, conduct aerial surveillance, and aid in intelligence gathering. This makes them valuable assets in border management, where monitoring vast border stretches, detecting threats, and acting swiftly are essential requirements.

The evolving nature of the threats faced by India highlights the significance of drones in border security. Drones are used by criminals and smugglers to circumvent physical barriers and conventional detection methods, transporting contraband, narcotics etc across border regions. In addition to using drones for reconnaissance and intelligence gathering, adversarial entities also survey border security infrastructure, troop movements, and sensitive installations. Integrating drones into border management systems is difficult, even though they present a wealth of opportunities. It is crucial to establish robust regulatory frameworks and legal guidelines for drone usage to ensure safety and responsible operation. The development of effective counter-drone systems is necessitated by technological limitations, such as detecting and intercepting small drones with advanced manoeuvrability. In addition, the training and development of personnel involved in the operation and maintenance of drones are essential for maximising their potential in border management.

Despite these challenges, the advantages and opportunities of deploying drones for border management are substantial. In addition, integrating automation and artificial intelligence technologies with drones has enormous potential for advanced data analysis and decision-making processes. In India, initiatives and efforts have been undertaken to exploit the potential of drones in border management. The government has implemented policies and regulations to streamline drone operations, ensure their security, and facilitate their use in border patrol. Border security agencies have acquired and deployed drones for surveillance, intelligence collection, and border patrol, thereby enhancing their operational capabilities.

This article examines the threats, difficulties, and opportunities posed by drones in India's border management. Through analysis, this paper aims to illustrate how drones can bolster border security measures, improve situational awareness, and contribute to effective border management in India. By addressing obstacles, capitalising on opportunities, and fostering collaboration, India can increase border security and maintain the integrity of its borders by leveraging the potential of drones.

OVERVIEW OF BORDER MANAGEMENT IN INDIA

Border management is a complex and critical aspect of national security in India. India faces unique challenges in ensuring the integrity and security of its borders due to its vast geographical expanse and diverse borders shared with multiple neighbouring nations. The primary objectives of border management in India are:

- The prevention of unauthorised border crossings.
- The suppression of smuggling and trafficking.
- The prevention of hostile infiltration.
- The maintenance of peace and security in border regions.

India has 15,106.7 kilometres of land border and 7,516.6 kilometres of coastline, including island territories. In response to the recommendations of the Group of Ministers on Border Management, the Department of Border Management was established within the Ministry of Home Affairs (MHA) in January 2004 to focus on the management of borders and coastlines.[1] Each border presents its own unique challenges and requires individualised management strategies and resources. The border areas include mountainous regions, riverine regions, dense forests, and arid deserts, which further complicate border management.

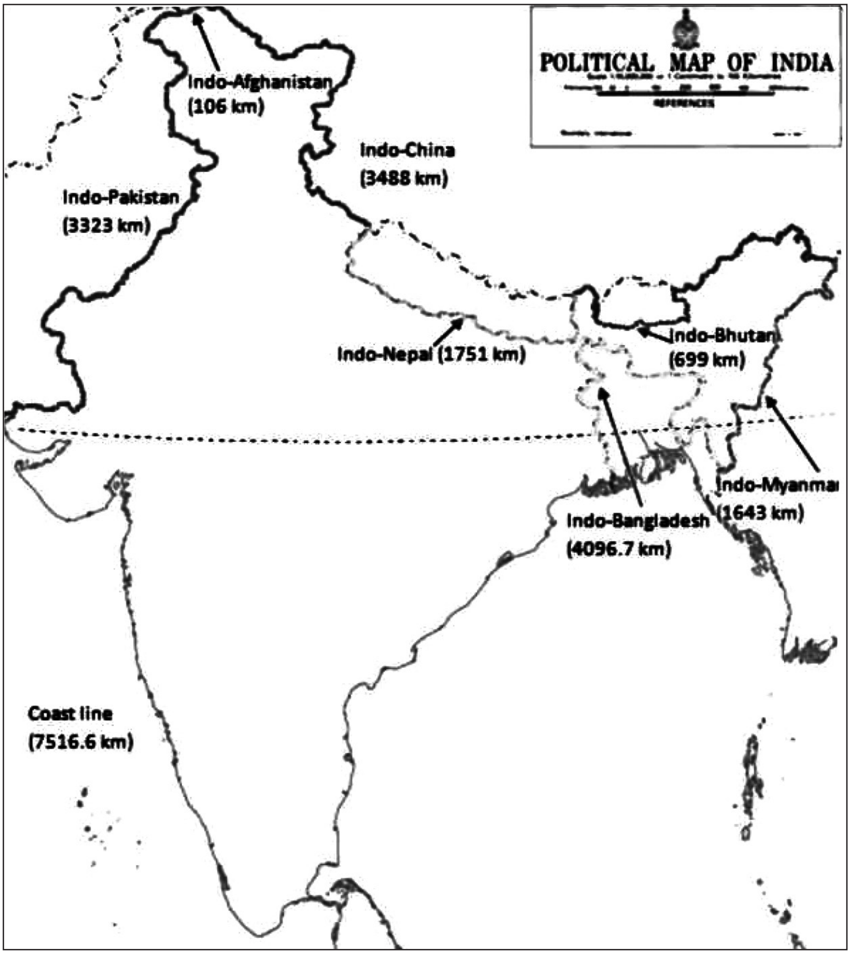
Border management in India is the responsibility of MHA agencies, particularly the Border Security Force (BSF), the Indo-Tibetan Border Police (ITBP), Sashastra Seema Bal (SSB), and Assam Rifles.

A variety of measures and strategies are employed to guarantee effective border management. Physical barriers, such as fences, walls, and border outposts (BOPs), serve as deterrents against unauthorised border crossings.

Technological advancements have significantly improved India's border management capabilities. Along the borders, sophisticated surveillance systems, such as radar networks, sensors, and camera installations, are deployed to monitor and detect suspicious movements. Communication networks are established so security forces can share information in real-time. In addition, aircraft, helicopters and drones are used for border patrol and aerial surveillance in heightened situations, resource availability.

The Border Management-I (BM-I) Division of the MHA has undertaken a number of initiatives as part of its strategy to secure the country's borders and build infrastructure in its border regions. India shares borders with the countries as depicted in **Figure 1** below:[2] To manage such vast borders, the BM-I division undertakes various systems and schemes.

Figure 1: International Boundary with Neighbouring Countries



Source: "Annual Report 2021-22," *Ministry of Home Affairs*, Government of India, https://www.mha.gov.in/sites/default/files/AnnualReport202122_24112022%5B1%5D.pdf accessed on July 9, 2023.

The CIBMS has been installed as a pilot project on two stretches of the international border in Jammu, each spanning approximately 5 kilometres, and a 61-kilometre project is nearing completion in Dhubri, Assam.[3] The 61 kilometres of the border area in Dhubri, where the Brahmaputra enters

Bangladesh, consist of vast char lands and countless river channels, making border patrol difficult, particularly during the monsoon season.

To address these issues, the MHA has decided to employ technological solutions to enhance the manpower capabilities of the BSF on the ground. As part of CIBMS, these two projects will aid in integrating manpower, sensors, networks, intelligence, and command and control solutions to improve situational awareness at various levels of hierarchy and facilitate prompt and well-informed decision-making and rapid responses to emerging situations.

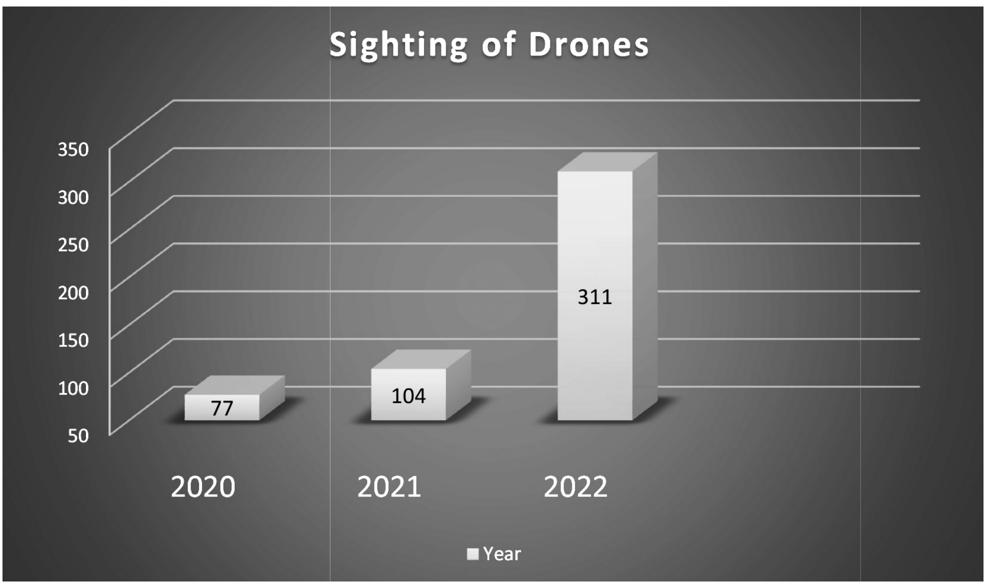
CIBMS entails the deployment of a variety of cutting-edge surveillance technologies, including thermal imagers, infrared and laser-based intruder alarms, aerostats for aerial surveillance, unattended ground sensors that can help detect intrusion attempts, radars, sonar systems to secure riverine borders, fibre-optic sensors, and a command and control system that will receive data from all surveillance devices in real-time. Implementing CIBMS projects along the Indo-Pakistan and Indo-Bangladesh borders will significantly improve the capabilities of the BSF. Stages II and III will include 153 kilometres and 1,802 kilometres, respectively, of riverine, delta, and estuary areas, waterlogged and swampy areas, creek areas, plain areas prone to heavy fog, densely populated border areas, hilly regions, tropical jungle areas and deserts.[4]

Drones are valuable assets for monitoring remote areas, detecting infiltrations, and enhancing the overall situational awareness of border security forces due to their adaptability, manoeuvrability, and cost-effectiveness. In recent years, the government has acknowledged the potential of drones in border management and taken steps to integrate them into the existing security infrastructure. With the implementation of the Drone Rules 2021, which define operational boundaries, licencing requirements, and safety protocols, the regulatory framework for the use of drones has been strengthened. Border security agencies have acquired and deployed drones for surveillance, intelligence collection, and border patrol, enhancing their operational capabilities. Collaborations with technology firms and startups promote innovation and customised border management solutions. Research and development efforts continue to advance border security technologies and strategies.

THREATS POSED BY DRONES IN BORDER MANAGEMENT

While drones present numerous opportunities and benefits for border management, they also pose significant threats that must be addressed. In the context of India, where terrain, topography, and altitude vary along the border, its security is of the utmost importance. Identifying, comprehending, and mitigating these threats is essential. Individuals and criminal networks can use drones to circumvent physical barriers and traditional surveillance systems in order to cross borders illegally. This presents a formidable obstacle for border security forces tasked with detecting and interdicting such illegal activities. Not only does this undermine national security, but it also bolsters illicit networks and organised crime.

Figure 2: Unauthorised Drone Incursions into Indian Territory (2020-2022)



Source: Authors articulation information culled out of an article by ANI.[5]

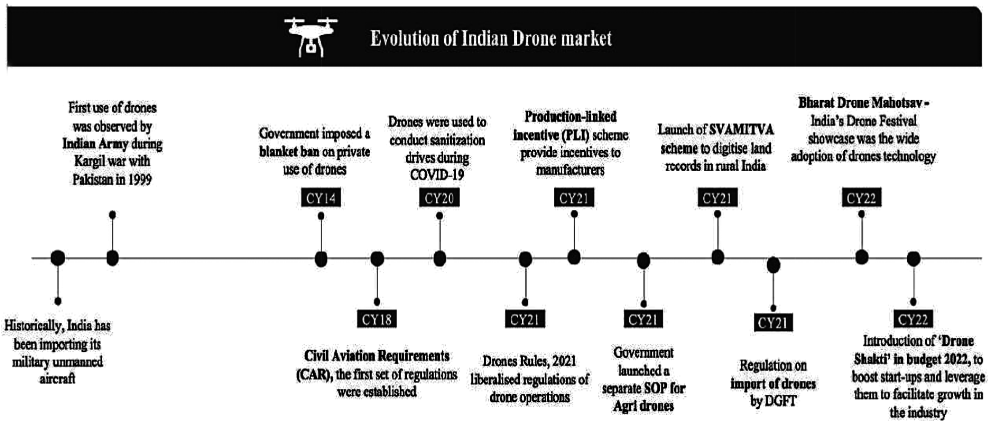
The information depicted in **Figure 2** depicts unauthorised drone incursions into Indian territory. Drone sightings have increased along the International Boundary (IB) and the Line of Control (LoC) in Jammu and Kashmir in recent years. A total of 492 drone sightings were reported by the BSF, including 311 in 2022, as compared to 104 in 2021 and 77 in 2020.[6] This trend demonstrates that drones are Pakistan's primary weapon in its proxy war with India. Drones are used for both kinetic and non-kinetic operations.

The use of surveillance and intelligence-gathering drones by hostile entities poses a threat to border security infrastructure, troop movements, and sensitive installations. To their advantage, adversarial actors, such as terrorist organisations and hostile nations, can use drones to gather real-time information on border security measures. Due to their small size, low-altitude flight, and advanced manoeuvrability, detecting and intercepting drones is technologically challenging. Traditional radar systems might have difficulty detecting drones, particularly those flying at low altitudes. In addition, drones can use techniques such as terrain masking and swarming to avoid detection and interception, making it difficult for border security forces to neutralise them effectively.

EVOLUTION OF DRONE INDUSTRY

Till 2014, the Directorate General of Civil Aviation (DGCA) under the Ministry of Civil Aviation (MoCA) banned the use of commercial drones in India until it formulated proper rules and regulations to govern their usage. In 2018, the DGCA released the Civil Aviation Requirements (CAR), which established a paperless procedure for filing permits for drone activities and registering licences for drones, owners, and pilots. Apart from defence, drones came into commercial action after 2018. With the new Drone Rules 2021', individuals and organisations in India are set to find it easier to own and operate drones, setting the stage for the broader use of drones in the country. As a part of reforms to make India a global drone hub by 2030, the government also launched the Production-Linked Incentive (PLI) scheme for drones and drone component companies in September 2021 to enable drone manufacturing in India. The pictorial depiction in **Figure 3** below sums it up.

Figure 3: Evolution of the Indian Drone Market



Source: Drone Industry Report. Indian UAV/Drone Industry, June 9, 2023, p. 43. https://ideaforgetech.com/investor-relations/industry-report accessed on July 11, 2023.

CHALLENGES IN BORDER MANAGEMENT

There are several challenges that must be overcome before drones can be utilised to their fullest extent in border management, despite their enormous potential. These challenges include regulatory frameworks, interoperability, technological limitations, and capacity building. To address these threats, multiple mitigating measures must be implemented.

COUNTER-DRONE CAPABILITIES AND MEASURES

It is imperative to develop effective drone countermeasures. Implementing robust detection systems that employ radar, acoustic sensors, radio frequency (RF) detection, and electro-optical technologies can aid in identifying and tracking unauthorised drones. Such systems must be able to detect small, low-flying drones to provide complete border coverage. This can include using radio frequency (RF) jammers to interfere with the drones' control signals and kinetic interception mechanisms such as net guns or directed energy weapons to disable or destroy the drones. Additionally, the regulatory framework should address the utilisation of counter-drone technologies for border management. The establishment and dissemination of policies and procedures should be prioritised. To prevent unauthorised drone interference, regulations should ensure that counter-drone measures are implemented within legal parameters and punitive provisions.

Enhancing Collaboration and Information Sharing

Improving collaboration and information sharing between border security agencies, intelligence agencies, and technology providers is essential for staying abreast of emerging threats, sharing best practices, and developing effective countermeasures. Regular intelligence sharing and joint training can assist in the development of a proactive defence against drone threats. Currently, all security agencies utilise a few time-tested and evolving mechanisms. However, there needs to be more real-time interoperability and a connected network along the border due to the extensive border length, the absence of a common communication and data network, and the deployment of multiple security agencies all along the border and in its immediate depth. Complexity exists in integrating drones into existing border management systems. Integrating data, sharing information, and facilitating interoperability between drones and ground-based surveillance systems is essential. Compatible communication protocols, data standards, and analytic frameworks must be developed to enable real-time collaboration and decision-making.

Compliance and Enforcement

To ensure adherence to the regulatory framework, it is essential to develop compliance monitoring and enforcement mechanisms, especially for border management. This requires regular inspections, audits, and evaluations of drone operators to ensure compliance with licencing requirements, airspace rules, and privacy protection measures. Clearly defined and implemented enforcement actions are required, such as penalties for noncompliance or unauthorised operations. Additionally, regulations should mandate the implementation of counter-drone technologies for border infrastructure protection. Fortunately, the liberalised Drone Policy 2021 has been able to cover most of these regulatory frameworks to a large extent. This policy may be further refined every two years to make it more punitive.

Technological Limitations and Infrastructure Requirements

Utilising drones for border management effectively necessitates the application of advanced technologies and a robust infrastructure. Effective drone operations require high-resolution cameras, real-time data transmission, secure communication networks, and dependable power sources. Establishing drone operation centres, charging stations, maintenance facilities, and secure data storage and processing facilities are included in the infrastructure development. Infrastructure must be strategically positioned to provide optimal coverage and facilitate drones' rapid deployment and maintenance. Moreover, dependable power sources and communication networks are essential for drone operations to continue uninterrupted.

Training and Capability Building

It is essential to ensure the availability of trained personnel and develop their capability to operate and maintain drones effectively. In addition to counter-drone technologies, training programmes should cover drone operation, data analysis, and interpretation. Essential to a successful implementation is the development of a skilled workforce capable of handling drone operations and responding to potential security threats. Conducting pilot projects and field trials to validate the efficacy of drones in border management operations and establish best practices is essential today. Combining theoretical instruction, practical exercises, simulated scenarios, and hands-on training with actual drones can facilitate training and capacity building. Collaborations with training institutions, industry experts, and seasoned drone operators can improve the quality and applicability of training programmes. By investing in comprehensive training and capacity-building initiatives, India can cultivate a workforce capable of utilising drones for border management. This ensures the safe, efficient, and responsible deployment of drones, improves border security operations, and enables effective responses to emerging threats and challenges. Indian Air Force (IAF) can take the lead in training the security agencies, as is being done in isolated cases.

Incident Reporting and Investigations

Establishing incident reporting and investigation procedures is required to monitor and address any safety or security incidents involving drones. This includes requirements for reporting accidents, near-misses, and unauthorised drone activities. Developing a centralised reporting mechanism ensures that incidents are thoroughly investigated, lessons are learned, and risks are mitigated as required.

Secure Communication Networks

It is essential for border management to provide secure and dependable communication networks for drone operations. Drones rely on communication links to transmit real-time data, receive commands, and stay connected to ground control stations. Establishing encrypted and interference-resistant communication systems prevents hostile entities from gaining unauthorised access, jamming signals, or intercepting data.

Data Management and Processing

During border surveillance operations, drones generate vast quantities of data with the help of sensors and cameras. Real-time analysis and interpretation of this data require efficient data management and processing systems. Implementing advanced data analytics, artificial intelligence (AI), and machine learning techniques can facilitate the extraction of actionable insights and the prompt execution of decisions.

India can strengthen its border security and reduce the risks posed by drones by addressing these threats and adopting a multi-layered approach to counter-drone measures. Investing in the research and development of anti-drone measures is essential to stay ahead of emerging threats, foster collaborations with technology firms, and continuously adapt border security strategies to effectively manage the challenges posed by drones in border management.

OPPORTUNITIES THROUGH DRONES IN BORDER MANAGEMENT

Drones have emerged as a crucial technology in border security, with capabilities that improve surveillance, response, and the overall efficacy of border management. The significance of drones in India, a country with extensive and diverse borders, cannot be overstated. Utilising drones for border administration offers numerous opportunities to improve security, efficiency, and efficacy. Drones provide unique capabilities that complement conventional border security measures and provide valuable information for decision-making. Utilising such opportunities can substantially enhance India's border management operations. Drones can revolutionise border security operations by creating new opportunities for surveillance, interdiction, and intelligence collection. The advantages that drones offer to border management are discussed in detail below.

Enhanced Situational Awareness

Drones equipped with sophisticated cameras, sensors, and imaging technologies provide a bird's-eye view of border regions. They provide capabilities for real-time aerial surveillance, increasing situational awareness along India's borders. By providing a bird's-eye view, drones allow for a rapid and precise assessment of border situations. They can traverse vast swaths of boundary regions, including remote and inaccessible regions, posing difficulties for ground-based patrols.

Effective Border Surveillance and Mapping

Drones can cover vast areas efficiently, overcoming geographical obstacles and reaching remote border regions inaccessible to ground-based patrols.

With their aerial mobility and agility, drones enhance border security agencies' surveillance capabilities and resource allocation. Drones aid in the mapping and monitoring border regions by producing detailed maps and 3D models. These facilitate resource planning, infrastructure development, and the identification of areas of vulnerability. Regular drone surveillance also helps track changes in border landscapes, such as illicit activities, incursions, or natural disasters, enabling timely interventions.

Counter-Smuggling and Anti-Terrorism Operations

Drones play a crucial role in detecting and intercepting illicit activities and combating terrorism along the border. They can identify concealed tunnels, detect contraband, and aid in interdiction. Drones with thermal imaging cameras and advanced sensors can detect heat signatures and trace movement in low-light conditions. By utilising the capabilities of drones, border management agencies can improve their anti-smuggling efforts and the overall security of border regions, particularly in the J&K, Punjab, Rajasthan, and Kutch regions.

Rapid Response and Mobility

Drones offer swift and mobile capabilities for addressing threats at the border in a timely manner. They can be rapidly deployed to monitor suspicious activity, respond to illegal border crossings, and support search and rescue operations. Drones with real-time video streaming enable border security personnel to assess potential threats remotely, make informed decisions, and effectively allocate resources. Drones are valuable assets for addressing dynamic border security challenges due to their agility and mobility.

Intelligence Gathering

Border management uses drones as intelligence-gathering tools, collecting data, imagery, and video footage, providing valuable insights for analysis and decision-making. Advanced data analytics and visualisation techniques can be applied to drone-captured data to identify patterns, detect anomalies, and extract intelligence that can be implemented. This allows border security agencies to respond proactively to new threats and make informed operational decisions.

Technological Advancements

Utilising drones for border management promotes technological advancement and innovation. As drone technology evolves, new features and functionalities emerge, enhancing border security capabilities. This encourages the development of advanced sensors, communication systems, autonomous navigation, and artificial intelligence (AI) algorithms, making it possible for drones to operate for longer durations, carry advanced payloads, navigate complex terrains, and analyse vast amounts of data in real-time. Integrating geospatial technologies and geographic information systems (GIS) improves the capabilities of mapping, spatial analysis, and geolocation capabilities. Such partnerships enhance the efficacy of drones in border management and permit proactive, intelligence-driven decision-making. Expanding the drone industry provides opportunities for collaborations with technology companies, start-ups, and research institutions, resulting in customised border management solutions. Border management agencies can unlock new opportunities to enhance security if they remain at the forefront of technological advancements.

Cost-Effectiveness

Border surveillance with drones is more cost-effective than traditional methods. They can efficiently cover large areas, reducing the need for manpower and physical infrastructure. This cost-effectiveness enables border management agencies to strategically allocate resources, optimise manpower utilisation, and invest in other crucial aspects of border security. According to a study by the MHA, using drones for border surveillance can save up to 60 per cent compared to conventional ground-based surveillance methods.

CONCLUSION AND RECOMMENDATIONS

The increasing recognition of the importance of drones in border security is reflected in the initiatives taken by the government. The Drone Rules 2021 and the proactive adoption of drones by border security agencies demonstrate a commitment to harnessing the potential of drones in border management. The government has acknowledged the value of drones in border security, leading to increased procurement and deployment by border security agencies such as the BSF and the Indian Coast Guard (ICG).

Having seen the complexity of border management, threats, challenges, and opportunities in the revolutionary drone sector, it is essential to analyse the mitigating measures to contain the misuse and misadventure of drones by inadvertent or deliberate use by non-state actors. Certainly, the entire length of the international boundary cannot be defended with the help of drones due to the vast, varied, and harsh terrain. Any amount of effort would be less than having impregnable borders. Notwithstanding this caveat, a phenomenal scope exists for strengthening the government and MHA's initiative towards secure borders. A few of the steps are mentioned below.

Focus on Counter-Drone Capabilities

The liberalised drone policy and ease of access, both economically and operationally, have yielded the possession of drones by anyone who desires. It is evident from the boom in the drone manufacturing or assembly industry. A vision of India becoming a drone hub for the world by 2030 is helping the drone industry grow on a daily basis. However, similar proportional growth is not seen in the counter-drone capability. Security agencies like the BSF, Armed Forces, and state police would require huge numbers of potent counter-drone capabilities with longer ranges and both hard and soft kill capabilities in tandem. Apart from hard and soft kill measures, the Russia-Ukraine conflict has also showcased the relevance of electronic warfare (EW) capabilities, which need to be embedded into counter-drone equipment. Research and development in this field should also be the key results for drone manufacturers.

Joint Response Mechanism

Due to the peculiarities of borders being divided into IB, LoC, LAC, etc., the responsibility of guarding the border differs from place to place. There are multiple agencies, such as the Indian Army, BSF, ITBP, SSB, Assam Rifles, and Coast Guard, involved in the common objective of securing borders. Above all, the IAF is responsible for protecting Indian airspace as per the Union War Book. It is necessary to make the joint working and response mechanisms well known and to lay down policies for all concerned. It is also pertinent that the standard operating procedures be firmed up and practised regularly, to the extent of once a fortnight, which will ensure a foolproof response mechanism functioning within a few years' time.

Creation of Drone Air Space Management Cell (DASMC)

The Air Defence Identification Agency (ADIA) of the IAF currently manages a staggering number of flight plans at any given moment. Low-flying and difficult-to-track drones necessitate the establishment of a parallel airspace authority within the ADIA at geographically dispersed locations. It can be called the "Drone Air Space Management Cell" (DASMC).[7] The DASMC could be established at the respective security agency's Zonal Headquarters, fully integrated with the ADIA of the IAF, to defend the nation's skies in the designated areas and corridors. The cell would have to collaborate with the IAF's command and control centres, coordinating with the existing ADIA systems and the newly implemented Digisky platform. There should be a requirement that all sensors are always connected to this network. The sensors would remain switched on throughout the highly intense and vulnerable zones. In other areas, it could be activated along a filled flight path or in response to intelligence inputs. To equip the DASMC, the government and security establishment must establish a comprehensive need for sensors and anti-drone systems and recruit trained personnel. With a failsafe air space management strategy, this concept is feasible and implementable, despite the large number of DASMC that would be required.

Public Outreach and Trust Building

Last but not least, the integration of drones in border control relies heavily on public acceptance, knowledge, and support. The public should be educated about the advantages, vulnerabilities, and responsibility measures of drone use via public outreach programmes. Transparency in drone operations and clear parameters for data gathering and utilisation are likely to contribute to the development of public trust and collaboration. Engaging in proactive communication with the public is necessary via awareness campaigns, community engagement initiatives, and public consultations.

Gp Capt Swaim Prakash Singh is a cat AYE, MFC, Command Examiner, qualified APM, and AWACS Mission Commander with over 1000 hours of flying. He has also been Directing Staff at DSSC, Wellington.

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INDIA'S DRONES ECOSYSTEM: ENHANCING CIVIL MILITARY FUSION

Dr Ulupi Borah & Ms Arijita Sinha Roy

"The enthusiasm that is being seen in India regarding drone technology is amazing. This energy is visible, it is a reflection of the quantum jump in the drone service and drone based industry in India. It shows the possibilities of an emerging large sector of employment generation in India."

– Prime Minister Shri Narendra Modi,
Bharat Drone Mahotsav, 2022

Abstract

Drones being a dual use technology have not only changed the character of modern warfare but also transformed governance and commerce. Military drones can carry a variety of armaments, such as missiles, guided bombs and provide real time intelligence, whereas commercial drones serve several civilian purposes such as land digitizing, support climate resilient industry and logistics. India envisions becoming a Global Drone Hub by 2030, exploiting the Drone Revolution. However, the growth of drone industry is at a nascent stage in India and requires a deeper Civil Military Fusion, akin to countries like China and the US. The paper critically analyses the gaps that exist in the drones ecosystem and outlines several recommendations especially for the industry sector, research and policy framework to promote synergized relationship between the three stakeholders i.e., the Indian Armed Forces, Industry and Academia and how it can make India a hub of global drones by the next decade.

INTRODUCTION

Since the end of the Cold War, the character of warfare has undergone significant changes. The present geo-political environment demands varied ways to deal with threats, which included cross border counter-insurgency operations, conducting targeted strikes and Intelligence, Surveillance, and Reconnaissance (ISR) Missions. *Leveraging new military technology to meet these challenges is of utmost salience.*

Unmanned Aerial Vehicles (UAVs) or drones became a critical weapon as a part of ISR and punitive operations. India, the world's largest democracy and one of the most rapidly growing economies, has a significant impact on international political and economic issues in this century. *However, there are a few external and internal security concerns for the rising power. India faces threats from its neighbouring countries, primarily Pakistan and China, as well as cross-border terrorist groups.* To address these challenges, **it is imperative *to prioritise self-reliance in defence manufacturing* especially by *reducing foreign dependency* while countering these threats.**

For India, *military modernisation is a priority, and UAVs can be at the forefront to deal with these security challenges*. The Indian Armed Forces have already inked several deals with domestic drone companies. According to the latest report from consulting firm 1Lattice, the **UAV market is currently estimated at $43 million**.[1] *The next decade will* **witness a drone revolution**, *and this could be the finest opportunity* ***for India to become a Global Drone Hub by 2030***. To achieve this, India must concentrate on a few fundamentals, including cost competitiveness, reliability, high quality, and indigenousness. Additionally**, India requires a strong Civil Military fusion where the best military minds collaborate with the brightest industry professionals and academia**. This will definitely ***spur the growth of dual-purpose technology*** like drones and ***help to meet India's demands for both military and civilian use.***

CIVIL MILITARY FUSION (CMF) IN DRONE TECHNOLOGY

India lacks an evolved CMF Strategy unlike the US and China. *The benefits of CMF are manifold, offering the unique advantage of leveraging civilian* *technologies for military applications and vice versa*. This approach not only enhances economic viability but also significantly shortens development timelines.

Amidst the ongoing global crises, it is critical to note that they have severely disrupted the defence supply chains. **These disruptions underscore the need for a resilient and adaptive CMF strategy, thus, encouraging the *two stakeholders i.e., industry and the armed forces, to reduce the reliance on imports*.** There is an urgent need of *Atmanirbharta* (self-reliance) through cooperative relationships with friendly nations and partners. To achieve this *India needs to develop a strong CMF which would be based on a* ***judicious resource management, swift and fair procurement procedures, supportive policies and innovative R&D and technologies.*** India has already seen a spurt in defence export and industry participation in **Def Expo 2022** and **Aero India 2023** under **Make in India**.

However, *in an exclusive interaction,* ***a drone professional*** has opined that **India's CMF is still at a sub-optimal level**. *This is mostly due to* ***the military not being able to provide clearly defined requirements to its civilian counterparts***. He further emphasized **the importance of a structured roadmap**, *particularly given the fragmented nature of the civilian sector*. Such a roadmap, spearheaded by the military, would establish essential guidelines. This ***collaborative approach*** *is crucial for* ***fostering growth across all three sectors****, providing a* ***unified methodology*** *for effective cooperation.*

PRESENT GLOBAL DRONE SCENARIO & TRENDS IN CMF

The trajectory of drone development has been promising, given its 'game changing' effect on conventional warfighting. *Proliferation of drones by* ***state*** *and* ***non-state actors*** *has also steadily increased*. UAVs used for surveillance date back to the 1980s.[2] Post 9/11 attacks, the US escalated the use of drones to target terrorists' groups, as hunter-killers. Drones were recently deployed for *assassinating Iranian Major General Qasem Soleimani*.[3] Additionally, *drones were also deployed* ***to counter non-state actors like the Islamic State and Boko Haram****, and* ***lethal attacks using drones have steadily grown.*** However, the **Nagorno-Karabakh Conflict** (**2020**) *induced a paradigm shift in the use of drones.* The conflict *highlighted* that there are ***entrenched vulnerabilities in conventional weapon systems without specific drone defences.***

The 44 days conflict between Armenia-Azerbaijan was a harbinger to what was to occur in Ukraine. ***The ongoing Russia-Ukraine conflict has also highlighted the advantages of small and medium sized drones, calling for a revisit to CMF strategies in drone production.*** *Existing players like* **China** and *new entrants* **Iran** *and* **Turkey** are *revolutionizing the global drone market*. **Iran's *Shaheed 136*** drones are being leveraged by Russians, filling a capability until it can boost indigenous UAV manufacturing.

China's civil and globally acclaimed drone company; **Da-Jing Innovations (DJI)** *(大疆创新- meaning Great Frontier Innovation)* has transformed the global drone industry. It is estimated that ***China has sold $ 12 million worth drones to Russia*** to fill the gaps of combat drone, **especially DJI's Mavic 3**. Interestingly, *DJI commercial drones* **costing $2000 or even less** have made inroads into the war. **These DJI drones are now being purchased on several legal and illegal platforms, and being re-configured for military purposes.** These commercial drones although not having sophisticated configurations, have high precision to target and destroy.

In April 2023, ***Pakistan*** *imported the first batch of* ***Bayraktar Akinci*** combat drones from ***Turkey***,[4] in spite of Pakistan's growing economic challenges. Additionally, Pakistan has been importing the ***Chinese Cai Hong-4 (CH-4)*** and the ***Wing Loong-II*** since 2018, in order to increase its military infrastructure. During the Galwan Standoff, *both* **India and China** *employed drones for* ***monitoring the frontiers***. ***MQ-9 SeaGuardian*** drones, on lease to Indian Navy, *were employed by the* ***Indian Navy*** *to monitor Chinese activity in the* ***Indian Ocean Region (IOR)*** *post the Galwan Valley clash in June 2020.*[5]

India's border disputes and the evolving nature of modern warfare in the ongoing Russia-Ukraine War highlights *the need to integrate a* ***coherent CMF strategy for the drones ecosystem*** **and fill the gaps between *policy and technology development* in the country.**

GLOBAL CMF MODELS IN DRONES

India is a largely new entrant to leveraging drone technology but has made great strides in incentivizing and promoting drone industries while also nurturing talents to have drones manufactured indigenously. Nevertheless, it is essential to draw key lessons from leading drone exporting countries.

US. The American drone market is expanding and by 2024 it is predicted to increase threefold. The *market for drones is divided* into *catering the drone supply based on two factors-**application** and **geography***. A **collaborative drone community** and **technology adoption** *remain the **key characteristics for the development of drones in the US.***

Source: The Drones World, 2022 URL: https://thedronesworld.net/drone-industry-in-the-us/

Drone policies in the US are monitored by the ***Federal Aviation Administration (FAA)*** that ***issues regulations***, ***expands opportunities for R&D*** *and also* ***integrates industrial policies*** *to* ***create an interactive drone ecosystem*** *in the country*. Drones have expanded in the US to an extent where leading *companies like* **Amazon** have introduced ***drone delivery*** **services** known as **'Prime Air',** enabling same day delivery.

In order to *encourage the use of drones in the commercial sector*, drone manufacturers are ***working with service providers to offer cutting-edge technology-integrated drone solutions***. Additionally, *the FAA* also **identifies Center of Excellences (CoE) designated to conduct quality R&D** by *leading Universities* across the country that look into critical areas for the successful integration of drones in the US's airspace. The **FAA is presently collaborating** with the **National Aeronautical Space Agency (NASA)** to resolve *issues related to Unmanned Traffic Management (UTM).* The FAA works closely with other agencies including business, academia, and government in order to frame rules, guidelines, and standards for drone operations.

China. The ***Civil Aviation Administration of China (CAAC)*** is the nodal agency that monitors drone development in the country. The *CAAC has established test areas known as* ***drone sandboxes*** *across the nation for* ***the testing of drone systems*** *and* ***operating procedures***. The CAAC devises **comprehensive regulatory programs to compliment the drone industry** in China.[6] A significant state-funded initiative to upgrade the nation's armed forces to "world class standards" is partially responsible for China's dominance of the combat drone market worldwide.

Chinese drones are characterized by *their cost effectiveness* and *delivery precision*. **China's unmanned programs are** ***inherently technological showcases*** **made to** ***encourage homegrown inventiveness***. Local businesses work on these initiatives to improve their capacity for prototyping, developing, and manufacturing.

China already operates a variety of UAVs, including different ***short-range systems***, tactical UAVS, such the *ASN-209 tactical UAV system*, and ***Beihang University-developed BZK-005*** *MALE reconnaissance UAV*. It is apparent that the PLA wants to enhance these capabilities.[7] Further, **China is said to have invested $322.6 million in the construction of a civilian R&D drone station in Taiyuan**, reflecting the significance of nonmilitary applications for unmanned systems. ***SF Express****, the largest delivery service in China, is* ***testing drones to carry packages*** *with the CCP's approval.*[8]

Turkey. Turkey has emerged as one of the top users and producers of armed drones globally. A ***Do It Yourself (DIY) strategy*** *can be attributed to this rapid growth*. The US Congress sanctioned sale of combat drones to Turkey in 2010 and 2012, because of concerns that the technology might be used against Israel. Therefore, *Turkey decided to make its drones with* ***two agencies; Turkish Aerospace Industries (TAI) and Baykar Makina.***

Today's *Bayraktar TB2* drone that are being employed in Russia-Ukraine conflict, was the **brainchild of *Selcuk Bayraktar*** who briefly pursued education in America's MIT only to return to Turkey to develop armed drones. *Baykar imported high tech parts that Turkey was unable to develop indigenously and since many of these parts could be used in either civilian or military applications*, and were therefore not subjective to export restrictions.

The shift began in the early 2000s, when Ankara set forward a plan to develop a contemporary, ***self-sufficient defence industry and promote local investment. The sheer volume of international deals that Turkey's defence companies have closed over the past few years indicates fast increasing demand, significant R&D investment, and an expanding source of diplomatic clout for Turkey***.[9] ***Techno-nationalism*** *and the* ***guided intervention*** *has completely transformed the drone's market in Turkey.* Further, *drones have given the Turkish government a new tool for projecting its foreign policy as a growing regional power*. Turkey is already exporting its HALE Bayraktar Akinci drones to the Middle East and Pakistan.

DRONE STARTUPS IN INDIA: AN OVERVIEW

The startups today are working on ***"Next generation Missions and Technologies (NGMT)"***. Although the growth of drones started in 2018, the shaping of this technology to command the skies in 2030 is projected.

Although there exists objectives and plans, the main focus should be on what is doable.

So far, India has seen the rise of several key players that are *making significant contributions to both* ***the domestic*** *and* ***international markets***. **Idea Forge,**[10] **State-owned Hindustan Aeronautics Ltd.,**[11] **Zen Technologies,**[12] **Bharat Forge,**[13] Lastly, **TSAW Drones, a startup originating from IIT Delhi,** is working on enabling logistics through drones.[14] There are a *few problems, which retard the growth of these startups*. **Competition from government programs and involvement from agencies like DRDO,**[15] **lack of alignment between civilian technology and military requirements, limited growth-phase funding, the complex certification process, and a lack of effective collaboration and interaction between the industry, armed forces, and academia,** has hindered the growth of these startups.

Air Marshal GS Bedi opines that *India's drone startup* ***should focus*** *on* **domestic manufacturing** *as* **70% of components** *are* ***still imported*** *and* ***then assembled*** *in the country.* There's also the *practice of* **rampant white-labelling** *which must cease for substantial sectoral advancement.*[16] Therefore, *perseverance* as well as *patience in terms of the industrial involvement* and *support in terms of schemes from the government and integration through civil military fusion are the key elements.*[17]

USAGE OF DRONES: AN INDIAN PERSPECTIVE

Drones are a *dual use platform* that can be used for either purpose with innovations and modifications. The different usage of drone technology ***by military, civil and non-state actors*** have been discussed in the table below:

Table 1

Capabilities	Military Use	Civilian Use	Use by Non-State Actors Against India's National Security
Endurance & Power	Persistent UAVs for long sky stay crucial for making critical battlefield decisions.		

	Solar & Air Launched UAVs.[18]		
Teamwork & Coordination	Manned Unmanned Teaming (MUMT) with Indian Air Force.[19]		
Data & Intelligence	Intelligence for unmanned combat air vehicle.	Digital land records	
	Leveraging Cyber-Physical Systems that encompass various layers, including sensing and perception.	Under the SVAMITVA initiative, drones have successfully mapped around 42,000 villages across several states, providing high-quality data quickly and cost-effectively.[20]	
Survivability & Security	Survival in contested airspace		Pakistan delivering drugs in Punjab, India.
	Drones that can operate in communication-denied or GNSS-denied environments		In June 2021, the terrorist attacks on the Jammu Indian Air Force facility verified fears that non-state organizations are using drones in terrorist activities.[21]
	Indian Army has acquired drones which remain impervious to current jammers in India, with kinetic counter drone strikes being the only effective means of neutralization		Chinese civilian drones easily available which could be used by non-state actors against India
Applications & Contracts		Drones in mining & forest preservation.	
		Climate resilient agriculture.[22]	

Source: Authors.

While the table above highlights the capabilities of drones in India, it also underscores significant shortcomings. **Currently, India does not possess the adequate capacity or the essential *sensors to detect, track, monitor, and neutralize drones should they become rogue*.**

GOVERNMENT POLICIES TO SUPPORT INDIAN DRONE INDUSTRY

India is presently undergoing a technological revolution that will bolster existing industries for '*Atmanirbhar Bharat*'. After *the liberalization of* **Drone Policy 2021,**[23] the government additionally introduced ***a series of policies to incentivise existing drone industries*** and further provide a platform for indigenization.

Table 2: Policy Measures Enhancing CMF

Name of Policy	Key Features
1. Innovation for Defence Excellence (iDEX)	• Engaging MSMEs, research and academia directly linked to the user at the R&D stage; • Aims to provide grants, funding and other potential forms of support; • iDEX Prime funding enhanced to Rs 10 cr.
2. Defence India Startup Challenge (DISC)	• Launched in 2018 and aimed at supporting Startups/MSMEs/Innovators to create prototypes and/or commercialize products/solutions; • Awards Rs. 1.5 crores in the form of grant/ equity/debt; • Successfully establishes synergy between R&D, Academia, Armed Forces and Industry.[24]
3. Development Cum Production Partner (DcPP)	• DRDO led DcPP engages industry as Development Partner (DP) during execution of drone projects; • Indian Industries get free access to DRDO patents.
4. Technology Development Fund (TDF)	• Provides financial support to MSMEs & Startups for design & development of innovative defence products; • Funding through the means of grants-in-aid.

5.	**Defence Acquisition Programme (DAP) 2022**	• Promotes "indigenization" for capital purchases; • The 'Buy and Make' category was replaced with 'Buy Global-Manufacture in India; • Amendments to Buy (Indian-Indigenously Designed, Developed and Manufactured)/ Buy (Indian-IDDM); • 'Make' category was divided into three subcategories; • Categories for 'Innovation' and 'Leasing' were added.
6.	**Production Linked Scheme (PLI)**	• PLI programme designed for drones and its parts; • Aimed at increasing India's drone manufacturing capacity by earmarking norms for both MSME and Non-MSME.
7.	**Open Challenge Programme (OCP)**	• Aims to "identity, recognize & reward" to the aspiring and early-stage tech innovators and entrepreneurs; • Assist entrepreneurs and innovators in strategic networking, seed funding, state-of-the-art incubation.

Source: Authors.

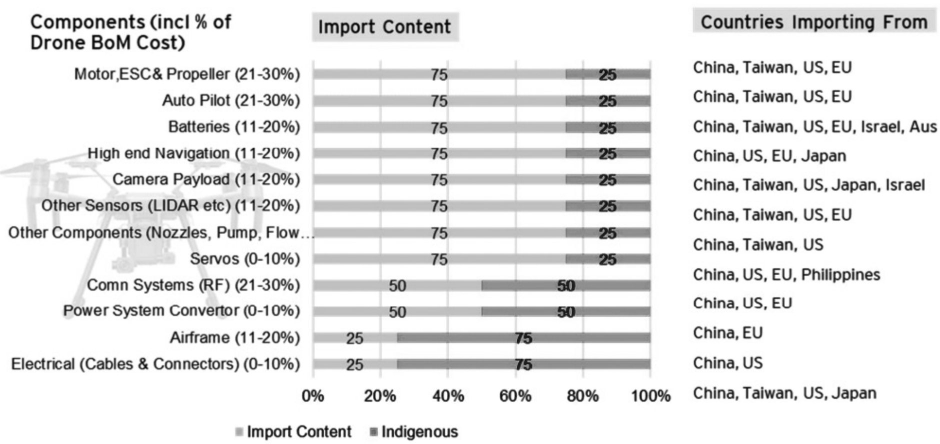
CHALLENGES TO THE INDIAN DRONE INDUSTRY

Policy Gaps

- **Absence of UTM.** Drone registrations in India have increased significantly, with 29,500 drones registered in 2021 and adoption is predicted to rise in the next two years. The *turnover of the Indian drone industry will increase from 60-80 crore to 900 crore by FY 2024.*[25] Despite the skyrocketing numbers for drone registrations, the ***question of integrating the UTM ecosystem*** with the ***Air Traffic Management*** *remains unresolved, though UTM Policy Framework was released on 24th October 2021*. The UTM ecosystem is envisioned as a cooperative extension of the existing Air Traffic Management (ATM) services, but for unmanned aircraft in airspaces where such ATM services are either not currently available or are unable to handle the anticipated volume of unmanned aircraft traffic.

The UTM is how the airspace can be managed 'Beyond Visual Line of Sight' (BVLOS) for multiple drone operations that can be conducted at low altitudes. Restrictions on private entities by **India's Drone Rules 2021**, identifies and **classifies fly zones into red, green and yellow**.[26] The ***US, Netherlands, Israel*** have resolved issues relating to UTM calling for a greater integration into the air defence system. Notably, the Israel Innovation Authority, Ayalon Highways Ltd, and the Israel Civil Aviation Authority developed new procedures and technologies to allow 150 kg drones to fly up to 150 km in and between urban centres.[27] Additionally, ***the lack of military UTM and accompanying technologies could become a source of attrition both during peacetime and conflict***. As a result, there is **an urgent need** for the development of ***remote identification systems and UAS UTM***, as well as their ***integration*** with the air defence system.[28]

- **Self-Reliance in UAV Manufacturing.** In *February 2022*, the **Directorate General of Foreign Trade (DGFT)** *banned the import of foreign drones to promote an indigenous drone ecosystem in India*. Nevertheless, this move ***did not limit imports of drone components*** for which India remains largely dependent on global players.



Source: EY Knowledge Report on Drones 2022[i]

[i] Ernest & Young and FICCI (2022), "Making India The Drone Hub Of The World" [online: web] Accessed 03 September 2023, URL: https://assets.ey.com/content/dam/ey-sites/ey-com/en_in/news/2022/09/ey-ficci-drones-report.pdf

- Although the government has formally adopted the import ban, *there continues to be grey areas between the ban on imports and the schemes like PLI*. **Domestic manufactures are not at par to develop and meet the quality threshold of leading drone exporting countries due to lack of funding and no dedicated R&D in this field.** *Critical components such **as electronic chips, batteries, software** are still being imported and therefore true 'Atmanirbharta' has been not achieved in manufacturing 'Made-In-India' drones*. A robust and self-reliant drone ecosystem that matches global standards, plagues the promising drone industry in India.
- **Undefined Trajectories for Drone Development.** India has many centres of excellence for drones and other emerging technologies. However, it ***lacks defined trajectories of development*** when compared to global players, particularly the US, Europe and China.[29] ***The trajectories of development generally followed by these countries are compartmentalized into Funding, Timeline and Objectives, whereas such tailored and defined trajectories are missing in the Indian scenario.*** The defence sector projects are said to follow certain defined and structured timeline, much contrasting to the civilian scenario. ***Additionally, there are no designated policies for the development of Civil UAVs in India.***
- **Proliferation of Drones**. Proliferation of drones is similar to gun proliferation and no substantive policies exist to counter it. **Non-State actors** ***and*** **anti-national elements** ***continue to proliferate drones using*** **illegal** ***and*** **unlicensed means**.

Industry Gaps

- **Matching Civil Tech to Military Needs**. The main emphasis of India's drone startups must be to enable the Armed Forces with better equipment. However***, the challenge is to map their engineering capability with the need of the Armed Forces.*** Therefore, the *challenge for the startups* **to map its technology** *to the* **need of the user** *continues to be a significant and an unresolved issue.*[30]

- **Ideating.** Ideating and then incorporating that technology to create any infrastructure is a daunting task. Looking at the historical records, *there are not many products that* ***most startups have been able to develop and deliver***.[31]
- **Seed Funding.**[32] Seed funding is often the *first hurdle; even after securing it, many* **companies struggle to obtain the crucial growth-phase funding**. This is particularly problematic for big-ticket startups aiming for large-scale projects, such as developing a substantial UAV program. *While they might secure an initial seed* ***funding of Rs 10 crore****, the overall program cost* ***could be as high as Rs 100 crore****, leaving the startup to* ***grapple with sourcing the remaining Rs 90 crore***. Although there is a policy assurance of procurement, the challenge of raising that additional capital remains a significant barrier. **It's crucial to understand that the journey from initial prototyping to a market-ready product involves multiple iterations, rigorous testing, and certification processes, making the funding aspect even more critical**.[33]
- **Certification**. Certification is a challenge for the startups. Currently, **Directorate General of Quality Assurance (DGQA)** handles military induction checks. However, it only assesses certain sensors and not the entire air vehicle. ***Startups lack exposure to certification processes, which currently lack a mechanism for resolution***. For, the development of manned aircraft, five years are dedicated to technology development, and an additional three to four years are required for testing and certification. The challenge arises as to **who would bear the funding for drone certification.**

Gaps in Academia

- **Lack of Interaction Between Industry, Academia and The Armed Forces.** While initial steps have been taken India still needs to bridge the gap between the three fraternities.
- **Academia's Contribution.** Academia *enjoys a less competitive landscape when it comes to government funding, compared to industry*. For instance,

institutions like ***IITs often receive swift financial approval from the Department of Science and Technologies*** for product development. *Despite this advantage, academia tends to* **focus more on the theoretical aspects of a product rather than its practical applications.**[34]

- **Big Industries Lack Research And Development (R&D).** Expectations of R&D from startups are pressing, but ***these startups lack the true capacity of fulfilling quality R&D.*** Even a giant R&D organisation like DRDO, with the central theme of R&D has not been able to roll out a UAV as of yet. Big business houses must get involved and spare some funds for that. *The Government has created a* ***National Research Fund, but how much of it will fall in this sector, cannot be ascertained***.[35] The big industries in India like the ***big five, Tata, Mahindra, Kalyani, Reliance and Adani, undertake limited R&D*** *and are mostly focused on Transfer of Technology (TOT).*

RECOMMENDATIONS

Policy Recommendations

- **Integration of a Comprehensive UTM System.** The approach towards ***UTM and the integration of drones with the Air Defence System and Digital Sky***[36] ***seeks civil-military actions***. The results of such approaches have started to surface especially after **the launch of Skye Air,**[37] ***UTM that allows drone operators across India to plan routes and avoid risks before any drone-related operation***. Skye Air UTM is a first of its kind and therefore sets a benchmark for more private players to address the issue of UTM integration. Additionally, ***registered third party users*** *may be allowed to extract data safely and securely from* ***Government led applications like Digital Sky*** *to facilitate in developing more* ***user friendly UTM applications*** *that can* ***accommodate special features pertaining to terrain, disaster, weather etc***. More research and technological developments are needed to create both civil and military UTM ecosystems. ***Civil-Military IDDM projects*** *can also focus on* ***creation of capabilities*** *that provide* ***safe integration of the UAVs in both UTM and military air space management.***

The development and implementation of UTM systems will be essential in enabling the safe and efficient integration of drones into the existing air defence system as the drone market continues to grow.

- **Develop Medium Term Objectives.** In the light of recent geopolitical developments, ***the need to reconfigure civilian drones for military purposes have arisen****, thereby calling the drone industry to boost production*. Nonetheless, ***the key drone manufactures are often hamstrung due to lack of concrete mid-term objectives.*** **Medium Term target** *specifications must be conveyed and monitored on a Medium Term policy level to monitor the development of drone prototypes.* Medium Term objectives must be outlined by the user prior to tendering to the industry.[38]
- **Need Of A Central Body.** Aeronautical Development Establishment (ADE) under DRDO has initiated projects with various agencies, *including VRDE Indigenous Engine development, CVRDE Landing Gear, DRDO HQ, SME (68), NSTL RCS Studies, CAIR Uplink Security, along with payload development such as LRDE and IRDE*.[39] However, there **lacks *a central oversight project management approach*. Thus, there is a need to partner with industry for various future platforms, using models such as MUM-T platforms, IDDM, and other suitable models**.

Industry Recommendations

- **Upgrade The Technology Markets**. One of the biggest challenges is that the Indian markets for drone technologies are still lagging behind when compared to China and the US. This is *mostly due to the fact that **drone proliferation** and **industrialisation has started very recently** i.e., in the last three to four years in India*. **Therefore, upgrading these technology markets is of great salience**.[40]
- **Involvement of End User at The Research And Development Stage.** It is very essential *to know and get the **end user involved right** at the **R&D stage***. This is critical because it **supports the startups in developing the requirements and at the same time find a ready buyer once it crosses the desired technological milestone.**[41]

- **Private Industry led R&D Funding.** A considerable share of fundings for the startups and companies are expected from government and government led agencies. For example, the **Indian Air Force's Mehr Baba Drone Competition** delivered the platform for the entry of Swarm drones led by Startups. Such tailored *competitions or funding programmes can* ***be encouraged and anticipated from key private industry*** *and* ***investors*** *to* ***promote quality and excellent R&D for drones in India.***

Recommendations For Academia/ Services

- **Role of Mandated Agencies.** ***Strengthening interaction*** between *the industries and armed forces is of utmost salience*. There exists mandated agencies to connect the two fraternities such as the Directorate of Aerospace Design for Air Force, Technology Development Acceleration Cell (TDAC) for Navy and Army Design Bureau for the Army. An ***enhanced role of these agencies will be able to provide enough information related to the requirements for the developers***.
- **Bridge The Gap Between Industry, Academia And The Armed Forces.** To bridge the gap between the three stakeholders, a major effort has to be driven by the armed forces. This is because *now the government is very clear about buying indigenous products and* ***approximately 75% of the capital budget is reserved*** *only for indigenous products.* Therefore, the biggest **responsibility is on the armed forces to align academia as well as startups to work together**.[42] Air Marshal Bedi opined that *academia and industry should collaborate more closely, and this partnership should also include key officers from the armed forces.* He pointed out that while officers are often deputed to organizations **like DRDO or HAL,** which have traditionally been involved in defence manufacturing, ***a similar model could be extended to the private sector, which is now being encouraged to participate in defence production.***[43]
- **Academia's Shift From Theoretical Concepts To Practical Application.** The fusion of academia, the military, and industry is a relatively new development, driven by initiatives like '*Atmanirbharta*' and the 'Make in

India' campaign. Therefore, it's unrealistic to expect immediate, sweeping changes in the active involvement of academia in practical applications. Nonetheless, *within the next ten years,* **India is likely to witness increased collaboration** *among* ***these three sectors in the development of homegrown drones***.[44]

To illustrate this recent shift, the MoU inked between *Idea Forge, and MIT World Peace University (MIT-WPU) can be highlighted*.[45] Similarly, the *Indian Institute of Technology Guwahati (IITG) has also entered in an MoU with Assam Electronics Development Corporation (AMTRON) and RC Hobbytech Solutions*. **Centre For Excellences (CoEs) on drones at IITs are being established.** This collaboration focuses on ***drone-based training, research, and development across sectors like agriculture, disaster management, wildlife conservation, and healthcare***.[46]

- **Drone Oriented Academic Courses.** Although the discourse on drones in India is remarkable, it is far from penetrating into educational curricula. The essentiality of *introducing MTech and PhD courses in UAS Technology have been flagged* earlier, but ***academic courses right from the elementary school levels can be nurtured in country***. The US has rolled out school programmes notably known as '**Drones in School**' which *provides platform for young students to further foster their* ***talents and develop entrepreneurial skills*** *related to drones.* **Similar programmes can be rolled out in India**.
- **Role of Think Tanks.** A greater CMF integration can be displayed by the *existing think tanks that* ***supplements and streamlines the connect*** *between academia, industry and user by* **providing platforms to discuss and deliberate future trajectories for drones in India**. ***Annual, bi-annual or quarterly seminars, workshops and webinars*** *should be organized* to provide ***a tangible direction*** *to* all stakeholders engaged in making India the next drone hub. Notably the **Annual Seminar by the Centre for Joint Warfare Studies (CENJOWS) and the Indian Military Review (IMR) on 'Unmanned Aerial Systems'** remains an exemplary case. The Think

Tanks can *leverage National Potential* by combining ***capital and creativity from the Industry, Science and Technology from Academia and experience from Government agencies/users***.

CONCLUSION

The drone ecosystem in India is promising. The dual nature of drones provides the scope and platform for several civil stakeholders to engage in the development of military UAVs. *The drone sector in India faces challenges in-**one, becoming self-reliant in critical emerging and disruptive technology*** and***two,emerge as a leading drone hub by 2030***. Nonetheless, **India needs to embrace a strong integration of CMF strategy to overcome the existing fallacies**. A closer integration between all stakeholders will promote transparency and credibility among Civil and Military UAS capability development programmes.

The industry, academia, and the armed forces ***cannot rely solely on the government*** *which mostly provides with guidelines and protocols.* A close partnership, with the armed forces guiding academia and industry is essential. The product's quality and utility must attract foreign investment, a vital factor for the drone industry.

The aggression of Russia in Ukraine altered the landscape of conventional warfighting and certainly *leveraging* **disruptive** *and* **dual use technologies** *have emerged equivalent to any country's national asset*. Countries across the globe have been leveraging and re-configuring civilian drones for military purposes. In India's ***'Kartvya Kal', CMF in Drones*** should be the way forward by ***harnessing the spirit of Atmanirbhar Bharat*** and creating a **cohesive and resilient drone ecosystem** that *streamlines a connect* between Academia, Industry and its Users.

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R&D AND INNOVATION STRATEGY: INDIA'S QUEST TO EMERGE AS GLOBAL DRONE HUB

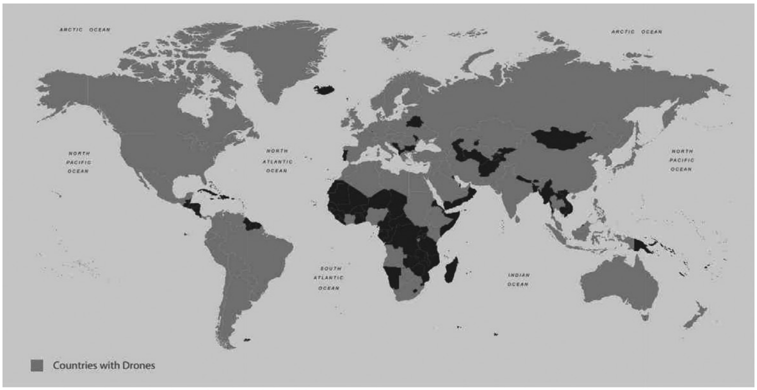
Ms Anamitra Banerjee & Shri Ujjawal Upadhyay

Abstract

The Indian armed forces released a proposal at the beginning of 2016 for the acquisition of over 5,000 drones over the next ten years, which is expected to cost three billion dollars. Due to several constraints and obstacles, India's R&D institutions were unable to build many effective drones for its military and commercial sectors, despite possessing a robust aviation R&D and production set-up. The recurring issue for India has been to transition from being an importer to an indigenous creator of aeronautical merchandise, particularly drones (UAVs). The paper investigates the scope of the Indian government's drone regulations and proposed mechanisms and strategies for implementing indigenous R&D. The study addresses major issues that must be addressed and suggests futuristic recommendations for drone R&D hubs.

BACKGROUND

Modern states are aiming to eliminate 'Boots on the ground' to minimise collateral damage and replace them with machines,[1] wherever they can be implemented. Keeping this in mind, the first-generation models of **Remotely Piloted Aircraft Systems (RPAS)** were developed for surveillance and assaults.[2] Initially viewed as a novelty, drones have evolved into regular military technology, producing an international system of facilities, bases, and test locations. Drones of varied sizes and capabilities have gradually infiltrated into the conflict zones of Syria, Ukraine, Yemen, and other regional war zones of the Persian Gulf, the East China Sea, and Africa.



Source: Michael C. Horowitz and Matthew Fuhrmann, "Droning On: Explaining the Proliferation of Unmanned Aerial Vehicles," October 24, 2014.

The earliest UAV purchased for targeting systems is the **RUM 2MB** of Bulgarian origin, employed by the Army's Air Defence (AAD) for target practice. Later, Northrop Grumman's KD2R5 was bought and utilised as an AAD target.[3] The ***Defence Research and Development Organisation's*** (**DRDO)** initiative to create the '***Nishant Unmanned Aerial Vehicle'*** triggered India's indigenous hunt for UAVs in the 1990s.[4] However, drone applications in the Indian subcontinent came into existence with the Kargil conflict of 1999. The solutions were for visual surveillance across the ***Line of Control (LOC)***.[5] The Indian Air Force (IAF) initially attempted to utilise an English Canberra PR57 aircraft, but it proved futile and strategically unsound due to Kargil's difficult terrain.[6] This highlighted a severe issue and the necessity for developing UAVs that met India's diverse needs. Losing a Canberra PR57 to the Chinese built Anza infrared-homing missiles by Pakistan, Israel's timely help during ***Operation Safed Sagar*** by covertly supplying IAI Heron and Searcher drones, enabled ISR capabilities along the LOC.[7]

Considering that 4 Nishant UAVs were developed, the Indian Army expressed discontent with the overall outcome. The poor status of the government's defense-industrial complex is demonstrated by DRDO's Nishant UAV. Despite the mobile variant ***'Panchi'*** being developed out of Nishant, against the new set of requirements, it failed to get inducted for regular use.[8]

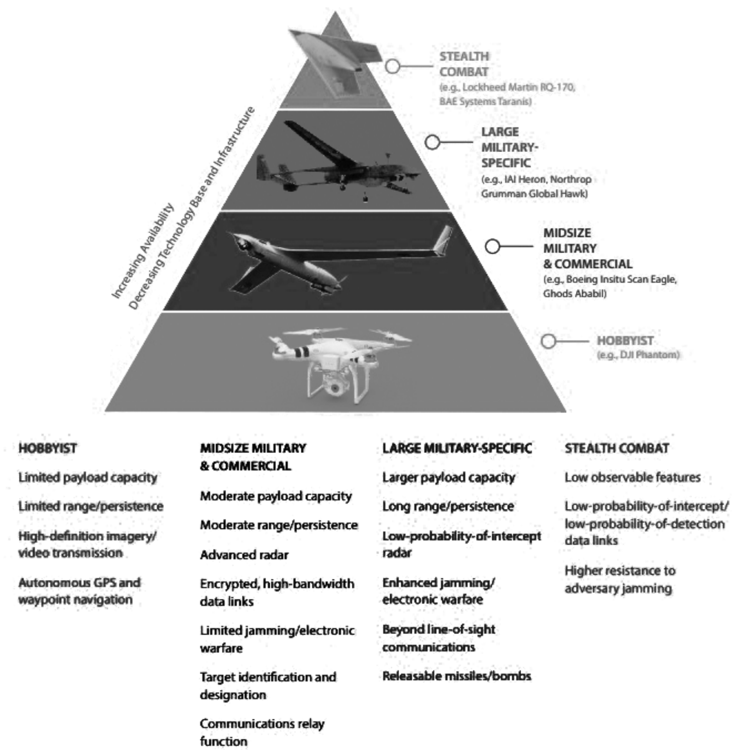
Since Kargil, India has acquired Israeli combat drones on a large scale to address tactical shortcomings. In 2009 IAF and Israel Aerospace Industries signed a $100 million contract for the procurement of 10 ***Harops.*** In February 2013, the IAF procured a new generation of Heron medium-altitude, long-endurance drones for $280 million. Presently, Israel Aerospace Industries' ***Harpy, Harop, IAI Searcher*** and ***Heron UAVs***, constitute the heart of India's drone arsenal.[9]

In 2013, India deployed Heron drones in a limited capacity to combat **Naxalism** in the ***Red Corridor*** insurgent areas in the East (Andhra Pradesh, Odisha, and Chhattisgarh).[10] The UAVs performed poorly in ISR capabilities due to thickly forested areas. This called for installing thermal imagers and infrared cameras for tracking insurgents despite dense forest cover. National Disaster Response Force, or NDRF, opted for utilising UAVs to aid Nepal in documenting the degree of devastation caused by the deadly earthquake of 2015, highlighting how Delhi has enthusiastically welcomed such pilotless planes, or ***"eyes in the sky."***[11] The ***Searcher UAV*** of Israeli origin was obtained by the ***Artillery's Surveillance and Target Acquisition (SATA)*** troops. It was employed to find targets in extensive detail and provide post-firing battle damage evaluations.[12] The Indian Armed Force at present heavily relies on the revised variant, Searcher Mark II. ***Operation Jhajjar Kotli***[13] in recent years, employed drones[14] to track down terrorists rather than choppers hovering above to locate the hiding grounds.[15] During the 2020-21 Galway Standoff with China, India acquired Israel's advanced Heron for reconnaissance missions in the eastern Ladakh area.[16]

In June 2023, the ***Indian Navy*** announced procuring ***30 Predator UAV***s from America. The Navy will additionally acquire four TAPAS-BH-201s.[17] Under the **iDEX**, the Indian Navy had highlighted the requirement for mini, micro and swarm drones.[18] In 2021, the Indian navy had signed a contract with BEL to acquire anti drone naval systems. The NADS detects and jams micro drones using radar systems electro-optical/infrared (EO/IR) devices, and radio frequency (RF) sensors. The DRDO's RF/Global Navigation Satellite System (GNSS) recognises the range utilised by the operating system and jams the transmissions. This stipulates the Indian military with both 'soft kill' and 'hard kill' capabilities for dealing with rapidly evolving airborne challenges.[19] ***ALS-50 Tata Advanced Systems Limited (TASL)*** recently handed over the initial set of indigenous ***ALS-50 Vertical Take-off and Landing (VTOL)*** Loitering Munitions to IAF.[20] Throughout the tests, the ALS-50 effectively demonstrated its ability to strike targets. It additionally showed its capacity to work in high-altitude settings amid testing in Ladakh.

GLOBAL PLAYERS IN THE DRONE ECOSYSTEM

With the emergence of Grey-zone warfare, prototypes are constantly being refined. Almost all nations having a more significant international presence are in pursuit of drones having enhanced agility and cutting-edge technology. As the global drone industry continues to expand, acquisition and authority over operating UAVs with diverse capabilities have become accessible to multiple stakeholders, which can be segmented into four categories distinctly supported by the chart below:[21]



Source: A World of Proliferated Drones: A Technology Primer

Governments throughout the globe have been developing drone R&D and regulations to enable drones for optimal efficiency.

- The examination of drone R&D projects performed by the United States, Israel, the EU, and Chinese reveals an emphasis on the establishment of a drone infrastructure comprised of testing locations, guidelines, standardisation, accreditation, and R&D projects. The number of research operations and demonstrations performed to create varied drone capabilities has served a significant part in promoting regional production and making drones operating within their airspace more feasible. Drone identification and tracking framework, guidelines, and procedures for approving big drones, solutions for increasing drone security, BVLOS operation, UTM, cyber defence, UAM, and Advanced Air Mobility (AAM) systems are among the significant developments that are currently being created. The ecosystem-building and research initiatives done by the United States, Europe, and China show significant commonalities.
- In case of Iran, IRGC has mastered the art of drone reverse engineering. The several navigation methods used by Iranian-designed drones make jamming and spoofing harder.[22] Iranian drones are cheaper, low-tech and are controlled via a jammable civilian GPS. To combat GPS jamming, Iran has removed the satellite connections from several UAV models. In contrast, its UAVs are often piloted using line-of-sight radio controls or are capable of employing GPS systems like those used in commercial sat-nav systems for self-guiding.[23]
- Turkish drones are economically viable, precise, durable, and efficient, with technical manufacturing and piloting plan capabilities that increase effectiveness. By restricting the degree of advanced technology used in production designs to only what is essential, such as HDR cameras, simple engines, low radar signature body designs, and—most importantly—AI software code technology for identifying visuals for aiming Turks

recently installed an autonomous digital warfare component to their ships to increase their lethality at a very minimal cost.

India lacks the supporting environment and key pillars, such as R&D evaluation centers, standardization between civil/combat/dual-use drones, needed to construct a high-value drone business, which inhibits big MNCs and independent entrepreneurs from developing new drone technology. As a result, India must construct essential foundations and an environment to foster R&D of a world-class, high-technology, important drone sector within India.

INDIA'S ATTEMPTS

Drones have been considered a ***'crucial force multiplier'*** by the Indian forces. This provides India with a platform to expand its defence drone infrastructure.[24] While the MSMEs can equip the troops, achieving the full capabilities of the military drone sector would necessitate careful nurturing and prompt resolution of some critical challenges. Between 1985 and 2014, India topped the list, accounting for 22.5 percent of worldwide acquisitions of unmanned aerial vehicles, next to Britain and France.[25]

Observing all these developments India has been making efforts to step up its game in drone research and development. Even the spearheads of India's defence sector: DRDO and ***Hindustan Aeronautical Limited (HAL)***, a premier institution for the development of fighters, helicopters and now drones have been making significant contributions to achieve these futuristic goals that have been set by the Government and deliver the Indian Armed Forces, world-class tech UAVs. In attempts to militarise the drones developed under the ***"Make in India"***[26] initiative, the following is an inventory of drones that the nation has been working on:[27]

DRDO Abhyas	Aeronautical Development Establishment (ADE) laboratory by Defence Research and Development Organisation (DRDO)
DRDO Ghatak	DRDO's ADE laboratory
HAL CATS	HAL and a private Indian firm (Newspace R&D)
Rustom- 1	DRDO
TAPAS-BH-201	DRDO's ADE laboratory
DRDO Imperial Eagle	DRDO's ADE and CSIR's National Aerospace Laboratory
DRDO Kapothaka	DRDO
DRDO Lakshya	DRDO's ADE laboratory
DRDO Netra	The Research and Development Establishment (R&DE) and IdeaForge, a Mumbai-based private enterprise
DRDO Nishant	DRDO's ADE laboratory
NAL/ADE Golden Hawk	DRDO's ADE and the CSIR's NAL
NAL/ADE Pushpak	DRDO's ADE and CSIR's NAL
NAL Slybird	NAL

Source: Military Drones in India.

The Aeronautical Development Establishment (ADE) and ***The Council of Scientific and Industrial Research-National Aerospace Laboratories (CSIR-NAL)*** jointly designed micro and mini-UAVs having endurance ranging from twenty minutes to an hour. Three Micro UAVs with completely autonomous capabilities were recently conceived: ***Black Kite, Golden Hawk,*** and ***Pushpak***. The ***Imperial Eagle*** and ***Slybird*** are two variations of two-kilogram class FWMUAVs. A live video surveillance system assures uninterrupted ISR throughout the entire flight, while a cutting-edge ground control facility manages the whole operation from takeoff to landing. It further allows digested info in real time, allowing users to capitalise on accessible ISR material. Imperial Eagle and Slybird are all equivalent to ***US RQ-11 Raven UAVs.***[28]

DRDO created a scanning laser system that was installed as a component of the ***C-UAS*** systems at the Red Fort before I-Day 22.[29] Depending on the wattage, it promises a long-lasting reach of 1.25 km. However, no major HPM technology has been documented in the nation to fight the UAS menace. The DRDO's indigenously designed D4 anti-drone system is manufactured by BEL. It can neutralise any potential danger within a 4 km range. It has multimodal tracking capabilities, including day/night sensors, radar systems, soft and hard kill choices through laser and jammer. The Indian Army submitted a Request for Proposal (RFP) for 20 C-UAS systems equipped to spot, track, recognise, and kill swarms/drones/UAS advancing concurrently from various directions.

Given the unclear legal future, homegrown entrepreneurs are creating and employing UAVs to achieve military and economic reasons. Drones are being utilised to deliver operations that include disaster aid to safety and monitoring of aerial imagery. Defence startups too have played an immense role in supporting the DRDO and the armed forces. Here is a list of noteworthy Indian drone startup companies:

- **Aurora Integrated Systems** offers drone-related services to both DRDO and the Indian Army independently with recon drones (Urban View), and Altius MK-II (medium-ranged, med-altitude drone capable of inspection, and targeting).
- **Edall Systems** offers design, planning, and production services, as well as drone research and education courses for learners. The firm also manufactures components for India's National Aerospace Labs and the DRDO.
- **IdeaForge** reportedly partnered with the DRDO to build the Netra UAV. The Netra UAV is a quadruple reconnaissance drone that is predominantly utilised by India's CRPF and the Uttar Pradesh Special Task Force. While IdeaForge's main business is surveillance and defence, the company also offers spatial modelling and researching, energy network recording, drone filming, managing crowds, commercial imaging, and organising events.

- **Garuda Robotic Systems** offers solutions for gathering and evaluating data received by UAVs, including agricultural and commercial questionnaires, safety, rescue operations, and transportation.
- **Zen Technology** has offered IAF with just a couple of C-UAS units with similar features but without the hard kill option however, the particulars are unclear.[30]

Under the Indian context, drones are divided into five different groups which is supported by the graph below.[31]

Type	Weight Range
Nano	≤250g
Micro	>250g<=2Kg
Small	>2Kg<=25Kg
Medium	>25Kg<=150Kg
Large	>150Kg

Source: The Print, June 29, 2021.

THE FALLACIES WITHIN THE COMBAT DRONE R&D ECOSYSTEM

While the atmosphere conducive to the R&D of combat drones appears to be emerging, significant obstacles remain unsolved throughout the past decade.

- September 1988 marked DRDO's initial attempts to develop drones domestically to meet the Army's requirements for ISR, target classification, shelling modification, damage evaluation, ELINT, and SIGINT.
  - ☞ With putting in about 90 crore for 20 years, Nishant's recurrent malfunction touchdowns, DRDO's egregious dearth of transparency and struggle to comply with the army's standards,[32] with succeeding CAG reports underscoring the department's rampant corruption. This left the military to operate without indigenous UAVs for a long time, which was supposed to be the army's eyes and ears, delivering

HDR pictures from the battlefield, aiding in target designation, and providing ELINT & SIGINT.[33]

- In March 2016, ADE presented a revised model of the Nishant UAV to be considered as an option for the second phase of deliveries. However, the Army maintained that Nishant and its modified versions were unsophisticated, and the field commanders perceived little reason to deploy them.

- ***ADE*** recognised the need to create an ***Autonomous Rotary Unmanned Aerial Vehicle*** (RUAV) in 2013. The authorization was obtained in March 2014, and Rs 10.69 crore had been allocated for the intended use. Surprisingly, the ADE failed to formulate a strategy for outcome realisation, with no representation of user bodies on the board of directors during the development phase as well as the production stage. Missing the deadline, the project was finally wrapped up in November 2015, with a Rs 6.53 crore expenditure.[34]
  - An investigation led by the ***Comptroller and Auditor General's*** (CAG) audit report investigated the rationales for stopping the project, rendering it infructuous spending. The ADE justified its position by stating the UAV failed to operate in semi/autonomous mode and hence the technology acquired during the project would be used in another project ***'Naval Rotary Unmanned Aerial Vehicle (NRUAV)'***, ensuring there was no squandering of capital. Following ADE's response, a thorough investigation was carried out into the NRUAV project and additional concerns were flagged.[35]
  - The authorization request for NRUAV was filed in July 2015, when RUAV was still operational. The project deadline was in May 2017, but the authorisation was approved in November 2015 with the understanding that one Chetak procurement under the Indian Navy would be calibrated with flight and data records. With HQ IDS alluding to the shortcomings of awarding the helicopter to the Indian Navy, the project proceeded to IAF to transform the manned helicopter into a rotary UAV.[36]

- ☞ The project was revamped from NRUAV to ***HELIDRONE*** in September 2017. In 2018, a corrigendum was issued against the project for modifying helicopters of any class into UAVs, further pushing the due date to November 2019. With the audit flagging these revisions, the ADE maintained ***'Chetak'*** had a significantly shorter operational life and that the amended mandate would assist in establishing in-house capabilities required for the upgrade of any chopper to a rotary UAV.[37]

- The ***Fixed Wing Mini UAV (FM-UAV)*** programme, approved in July 2010 suffered an identical outcome. The project was initiated to address the needs of the military and paramilitary groups. The CAG revealed that the project failed to involve any end-user representatives in the peer review committee.[38]
- The auditing team discovered that eleven of the sixteen endeavours assessed failed to include an outcome realisation strategy. With the issue of both labour and cost overruns, most of these projects were postponed from six months to six years. The report indicated at least the estimated expenditure of three projects increased from INR 40 lac to INR 369 crore.[39]

THE RISING IMPETUS FOR THE INDIAN DRONE ECOSYSTEM

While the market for combat drones still needs to materialise, drone makers can pique significant interest within the MNCs for various civil uses. Initially, the drone R&D sector was less explored, compared to the present with more than 300 start-ups and PSUs involved in the production and delivery alone. Until 2021, roughly sixty per cent of drone supplies were sourced from China, with around five percent of supplies coming from Western States. Third-party suppliers would often assist UAV/drone manufacturers and assemblers with components and additional necessities. The implementation of ***'Liberalised Drone Rules (2021)'*** opened avenues for sector-wise drone R&D. Since UAV acquisition is currently not permitted under ***'Completely-Built-Up (CBU), Semi-Knocked-down (SKD) and Completely-Knocked-down (CKD)'*** forms, a surge in patronage for ***Made in India*** drones has generated demand and created enormous opportunities for R&D within the MSMEs.[40]

- The Indian MSMEs at present are unable to match the capabilities of drone parts and critical tech and must rely heavily on imports. Under the Drone Rules, 2021 drone spare parts can be acquired either for defence or for research & development, or service repairs.[41]
    - ☞ Addressing the challenges, the Central government has launched a ***Production-Linked Incentive (PLI),*** initiative (2021) to boost the indigenous R&D of drone equipment.
    - ☞ The central government promised to retain the PLI value fixed at 20% for the entire 3 years, with consideration offered to the drone companies, as against the PLI rates of other sectors' PLI schemes that decrease with every year.[42]
    - ☞ The government has also set the minimum value addition standard for drones and their parts at forty percent of net revenue rather than fifty percent, giving a further boost to the drone sector.
    - ☞ The PLI Scheme includes a broad spectrum of drone elements including propulsion systems, batteries and related parts, flight and recovery mechanisms, power systems, airframes, navigation systems, flight control modules, cameras, communication systems, spraying systems, sensors, ground control stations, payload capacities, 'Detect and Avoid' mechanism, trackers, and other important security components. The authorities can periodically extend their inventory of appropriate elements as the drone industry improves. Further, the government has decided to expand the initiative's scope to cover the manufacturers of drone-related technologies.[43]
    - ☞ In addition to the broad parameters for selecting potential recipients, the government has indicated that the PLI System might be expanded or revised after assessing its effect in partnership with the intended sectors.

- Facilitating and clarifying the ***'Special Chemicals, Organisms, Materials, Equipment and Technologies (SCOMET)'***[44] licencing procedure, the Indian govt. has made attempts to identify drones as one of three major groups in the SCOMET list:[45]
- The ***Digital Sky platform*** is an effort by the ***Directorate General of Civil Aviation (DGCA)*** to offer a reliable and flexible structure that enables drone-related regulations such as ***NPNT*** (no permission, no take-off), which allows for flight authorizations electronically while also effectively overseeing autonomous flight operations and traffic. Digital Sky is designed as a practical, single-window platform that requires little user interaction and most licences are provided automatically. Dynamic aerial mapping is also offered on the Digital Sky portal, distinctly into three zones: green, yellow, and red. UAVs are forbidden to operate in green zones.[46]
- The extended border clashes and claims with the Chinese have exacerbated the demand for drones in ISR, operations, logistics, and target frontier posts. Under various initiatives, the Ministry of Defence (MoD) is assisting India's defence drone infrastructure.
  - ☞ ***The Innovations for Defence Excellence (iDEX)*** program supports the production of military-grade UAVs, presenting the current challenges and the needs of the troops. Startups bid their proposals to match those demands, and the most compelling proposal wins the funding to build their product. Most military-grade drones are currently being manufactured under this initiative. Further, for upgrading weapon systems as per requirement, ***The Technology Development Fund (TDF)*** issues credit to defence start-ups. The ***DGCA*** has also been granting nearly 7000 ***unique identification numbers (UINs)*** and close to 14 specific licenses for certain drones to the original equipment suppliers.[47]
  - ☞ The Indian Army alone has acquired nearly two thousand drones to improve ISR along the ***Line of Actual Control (LAC)*** and transmit supplies to outposts. It is additionally looking to procure UAVs that

can steer artillery fire, to improve the precision and efficacy of the weapons positioned across the border.

☞ The IAF's ***'Mehar Baba Competition'*** aims to encouraged domestic R&D, which is crucial for the advancement of specialised swarm drone system, stipulating a starting point for the application of these drones in combat.[48] In 2022, the Indian Army started the 'Him Drone-a-thon' initiative jointly with the ***'Drone Federation of India,'*** boosting India's drone industry to improve competencies to comply with the Army's mandates.[49] Although these efforts are beneficial for developing India's defence drone sector, they should be supported by acquisition requests.

WAY FORWARD

- Given that the existing start-ups already stand to benefit from it, there is room for MoD to expand its investment and assist other defence start-ups. In general, civil-military fusion is crucial to the development of the drone ecosystem.
- Government intervention is the key to generating economic viability for drones, allowing this nation to realise its unique technological capacities. The MoD should expand the iDEX, given its enormous scope for assisting with the design of military drones. At present, iDEX offers funds worth INR 1.5 crore for startups which is too little to expand the drone industry. Hence, the MoD as the intermediary holds the ability to generate a demand of nearly INR 75,000 crore within the civil domain plus INR 23,000 crore within the armed forces and security agencies.
- A pressing concern for start-ups is the dearth of R&D. These small firms have limited funds and are often reluctant to invest in producing items that the Indian troops are apprehensive about purchasing. To stimulate R&D, the military should allocate a small percentage of investments to test out pilot projects and accordingly give their feedback to the startups for further improvement of their goods, and if required to integrate additional indigenous spare parts.

- It remains unrealistic to anticipate any drone ventures to produce all its components. To be a pioneer in the indigenous drone sector, India needs to establish an optimal climate capable of supplying drone start-ups with locally built hardware like chips, propellers, engines, LiDAR, flight control systems, and so on.
- It may be predicted that the security and surveillance industry will see significant activities by big companies such as Google, Apple, Infosys, TCS and Wipro offering AI, IoT and machine learning coupled drone solutions.
- Atmanirbhar Bharat[50] is the final approach, but it needs to be hastened.
  - ☞ Research and development are typically an intensive process that should be carried out in conjunction with the acquisition. Nonetheless, the imbalance across the drone threats and solutions continues to exist.
  - ☞ Radars customised for LSS[51] threats, sophisticated jamming devices tailored made for unconventional bands, the production of secure and high-power lasers, HPM technologies, and unmanned counter drones with AI/ML features, are some of the immediate needs within the drone ecosystem.
  - ☞ The government needs to build strategies and bring in reforms to reduce red-tapism and make realistic goals. 100 percent indigenous projects will face certain obstructions that will cause unwanted delays. Hence, India can take lessons from the ***KF21 project of South Korea,*** instead of developing all the technology alone and loosing critical time, collaborating with nations and companies that have developed the tech is the most viable option. Developing tech while signing MoUs for ToTs will not only help cover the crucial gap and help mitigate the tactical gaps and provide the troops with necessary equipment at the earliest while incubating country's manufacturing and technological development capabilities.

  - ☞ Prospective platforms like light utility helicopters (LUH), light combat helicopters (LCH), and Hindustan Turbo Trainer-40 (HTT-40)—could all be outfitted with anti UAV technologies. Given their slow pace operating qualities, excellent maneuverability, fast launch capabilities, and enough payload carrying capacity, they have the capacity for serving out counter drone duties in particular threat situations.

- Agencies like MoCA, DGCA do not often lead projects for R&D. As a result, it's necessary to adapt and embrace a research and development-led strategy. Hence, the govt should set up an Inter-Ministerial Committee having representation from agencies and ministries engaged specifically with the UAV and Counter-drone sectors. This committee should be tasked with debates periodically to solve industry challenges and bottlenecks. The panel could also incorporate ideas suggested by any additional division, ministry, participants, or specialists as requested by the Chair. To render this industry economically viable and to grow the globe's leading center, the committee ought to investigate every challenge in design, inventions, restrictions, modern technical advancement, international supply chains, assessments, job creation, education and training, international standards, reciprocity complications, and tariffs. Moreover, India should formulate and have an anti-drone policy in place.
- For defence acquisition, India relies heavily on G2G agreements.
  - ☞ However, G2G transactions frequently succumb to a lack of sourcing viability. In addition, technology transfer is often obsolete, with minimal local production. The government should allow applicable Transfer of Technology in G2G Military transactions under the framework of UAV manufacture.
  - ☞ G2G-Strategic Partnerships ought to be geared towards solving Technology Readiness Level (TRL) deficiencies in studies,

development, production, and assessment technologies that have been recognised by DPSU's,[52] Indian R&D, and businesses.

- Drone evaluation architecture is an important component of the research & development ecosystem because it allows drone makers and experts to test the technology in real-life situations in a secure setting. Hence govt. intervention is necessary at several levels:
    - ☞ The government should formulate a centralised system through which states may submit proposals for testing locations.
    - ☞ There should be designated road maps for developing indigenously built drones and key initiatives should be in place for their induction under certain duration like 5-year plan, 10-year plan and so on.
    - ☞ Designated 'Sandbox' laboratories must be established in secure areas throughout the country. By expediting the design and development of UAV and C-UAV tools, testing facilities may bring in funds.
    - ☞ Governments must use public-private partnership (PPP) structures to incentivise spending on setting up, operating, and maintaining trial facilities.

CONCLUSION

Drone management is being considered by governments all over the world to keep up with the latest technology breakthroughs while also ensuring national security. Several countries, particularly America, Singapore, Australia, and South Africa, have authorised policies on drones, while some are discussing and debating on final rules. India has also taken an initiative in the right direction, providing greater flexibility in operating drones throughout the country, enabling the growth and establishment of a range of industries that wish to employ drones for their services. Despite the new laws that have entirely offered up the drone business to both domestic and foreign competition, the task is not finished. As the sector expands, new ethical and safety risks will develop that all parties must evaluate. To increase the general confidence in drones, every stakeholder must work together to guarantee that drone operations remain safe and beneficial.

Given the evolving R&D landscape, industry stakeholders may consider comprehensive conversations on regulations to be imposed, as well as an autonomous structure to ensure that the actions of certain reckless users don't give rise to a poor general perception of drones.

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51. LSS - "low, slow, and small" targets
52. DPSU – Defence Public Sector Undertakings.

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