Neil Renic & Johan Christensen

DRONES, THE RUSSO-UKRAINIAN WAR, AND THE FUTURE OF ARMED CONFLICT

DJØF PUBLISHING
IN COOPERATION WITH THE
CENTRE FOR MILITARY STUDIES

Drones, the Russo-Ukrainian War, and the Future of Armed Conflict

Neil Renic &
Johan Christensen

Drones, the Russo-Ukrainian War, and the Future of Armed Conflict

Djøf Publishing
In cooperation with the
Centre for Military Studies
2024

Neil Renic &
Johan Christensen
Drones, the Russo-Ukrainian War,
and the Future of Armed Conflict

Acquisition and Procurement

This publication is peer reviewed according to the standards set by the Danish Ministry of Higher Education and Science.

Cover: Kelly Chigozie Kjelsø Arazu

Print: Ecograf, Brabrand

Printed in Denmark 2024

ISBN 978-87-574-6197-8

Djøf Publishing
Gothersgade 137
1123 København K

Telefon: 39 13 55 00
e-mail: forlag@djoef.dk
www. djoef-forlag.dk

Editor's preface

The publications of this series present new research on defence and security policy of relevance to Danish and international decision-makers. This series is a continuation of the studies previously published as CMS Reports. It is a central dimension of the research-based services that the Centre for Military Studies provides for the Danish Ministry of Defence and the political parties behind the Danish defence agreement. The Centre for Military Studies and its partners are subject to the University of Copenhagen's guidelines for research-based services, including academic freedom and the arm's length principle. As they are the result of independent research, the studies do not express the views of the Danish Government, the Danish Armed Forces, or other authorities. Our studies aim to provide new knowledge that is both academically sound and practically actionable. All studies in the series have undergone external peer review. And all studies conclude with recommendations to Danish decision-makers. It is my hope that these publications will both inform and strengthen Danish and international policy formulation as well as the democratic debate on defence and security policy, in particular in Denmark.

The Centre for Military Studies is a research centre at the Department of Political Science, University of Copenhagen. The centre conducts research into security and defence policy as well as military strategy. Read more about the centre, its activities, and other publications at: https://cms.polsci.ku.dk/english/.

Copenhagen, June 2024
Kristian Søby Kristensen

Table of Contents

List of Figures, Tables, and Textboxes

Figures

Tables

Textboxes

List of Abbreviations

AI: Artificial Intelligence
CCW: The Convention on Certain Conventional Weapons
C-UAS: Counter Unmanned Aerial Systems
EW: Electronic Warfare
EDA: European Defence Agency
FMI: Forsvarsministeriets Materiel- og Indkøbsstyrelse
FPV: First-Person View
GGE: Group of Governmental Experts
ISR: Intelligence, Surveillance, and Reconnaissance
LAWS: Lethal Autonomous Weapons Systems
LM: Loitering Munitions
MALE: Medium Altitude Long Endurance
MLRS: Multiple Launch Rocket System
MoD: Ministry of Defence
MSTS: Multi-Spectral Targeting System
MTCR: Missile Technology Control Regime
NATO: North Atlantic Treaty Organization
PKK: Kurdish Workers' Party
RUSI: Royal United Services Institute
USMC: United States Marine Corps

Abstract and Recommendations

This report details the impact and implications of drone and counter-drone use in the Russo-Ukrainian War, drawing out lessons for future armed conflict. The accelerated pace of drone and counter-drone innovation, and the growing centrality of both in the defensive and offensive strategies of the Ukrainian and Russian militaries, virtually guarantee that this weaponry will play a prominent role in future warfare. If Danish policymakers underestimate this role, they risk being left ill-equipped to adequately harness – and defend against – armed drones going forward. Overestimation, on the other hand, may lead to a distorted techno-optimism that blinds military planners to the very real limitations of this technology. This report argues that drones are not, and likely never will be, a 'silver bullet'. They cannot overturn fundamental disadvantages on the battlefield stemming from poor logistics or deficiencies in force design, employment, and quality, and they retain limits that can only be mitigated, not overcome. As the Russo-Ukrainian War clarifies, however, the drone has unequivocally moved from a peripheral to a central aspect of inter-state war.

This change is best captured in three trends. Firstly, the *proliferation* of drone technology is changing rapidly: in quantity, with an increasing number of state providers, recipients, and available technologies; in quality, with the unprecedented and growing role of the private and public sectors; and in depth, with states recognising the importance of both a domestic industrial base and international trade links in meeting current and future drone and counter-drone capability needs. Secondly, the *battlefield use* of drones is evolving, with the most profound impact coming not from the high-end, military-grade drones that defined the War on Terror period, but rather the mass-produced and mass-deployed small, cheap, and commercial drones that have dominated the skies of Ukraine. The cost-effectiveness and ease of use of these drones, combined with their ability to enhance intelligence, surveillance and re-

connaissance (ISR) and combat operations, facilitates their integration into all levels of command going forward. This also makes vital the acquisition of effective but affordable counter-drone systems. Thirdly, the Russo-Ukrainian War is driving advances in military AI that include *autonomous drones*. Favoured as a way to offset counter-drone jamming and increase the speed and lethality of combat operations, autonomous drones have military potential but also pose significant technical, moral, legal, and strategic challenges.

This report provides a detailed account of these developments and formulates a set of recommendations that will empower Denmark to navigate a rapidly and profoundly changing drone landscape.

1. **Update the European and Danish mind-set on drones.** For decades, the European debate on drones has been shaped by the remote warfare conducted during the Global War on Terror in the 2000s and 2010s. The Danish debate has also placed heavy emphasis on Arctic surveillance. The primary focus in both has been high-end, military-grade drones. The debate must now be updated. The contemporary drone landscape has radically transformed, especially in relation to the surge of inexpensive, commercially available, disposable, and highly versatile drones, acquired and expended at scale. Militaries will operate on a battlefield saturated with drone and counter-drone technology, and they must plan for that future accordingly. The changing status of battlefield drones necessitates an equally significant change in doctrinal planning.
2. **Decide whether and how to acquire armed drones.** If the Danish government opts to acquire armed drones, the technology will need to be integrated into all levels of force design going forward. The ISR capability of drones alone will make this a necessity. However, Danish policymakers must also not lose sight of the fact that drones, for all their value, are an *additive* in war – they will complement and enhance existing systems but rarely replace them entirely.
3. **Invest in counter-drone systems.** For the Danish armed forces to operate on future battlefields effectively, significant investments in counter-drone technology are necessary, including electronic warfare and air defence systems. As with drones, this capability will take time, resources, and training, and Denmark must work to strike the right balance and accept the inevitable trade-offs; between effective-

ness, mass, scale, and cost. The best counter-drone system for Denmark will not necessarily be the strongest performing counter-drone system on the market – the procurement and development of these technologies requires a long-term cost-benefit analysis. It also requires the ambition and resources to act now. Delays in the procurement of counter-drone systems will leave Danish combatants dangerously exposed on the battlefield.

4. **Undertake a health audit of the current relationship between domestic drone suppliers and the Danish armed forces.** Moving forward, the logistical pressures to maintain drone stockpiles will be more akin to bullet and artillery shell acquisition than tanks and aircraft. To meet domestic needs and to succeed in the multi-billion-dollar drone-procurement market, Denmark will need flexible and responsive bureaucracies, innovative drive, the space and culture to experiment at strategic and tactical levels, and strong government-industry ties. Ukraine is developing and modifying drones at a rapid pace in a low-regulation environment due to an existential Russian threat. Denmark must consider both the advantages and risks afforded by this easing of regulatory burdens. The Danish approach should not mirror Ukraine, but rather its own internal review of future military exigencies and responsibilities.
5. **Assess the current level of vulnerability of critical infrastructure to drone attack.** Denmark should prepare for a future in which terrorists and other hostile actors have ever-greater access to cheap and effective means of societal disruption. This again speaks to the importance of cost-effective counter-drone investment. The more advanced a given defensive system is, the more costly it is likely to be to develop, resupply, and maintain.[1] Critical infrastructure defence, just as with military defence, will need to prioritise *sustainable affordability*.
6. **Develop a comprehensive policy on the development and use of autonomous weapons.** Denmark must follow the lead of its allies, such as the United Kingdom and the United States, and formulate

1. John Barret, "You Go to War with the Industrial Base You Have, Not the Industrial Base You Want," *War on the Rocks*, August 16, 2023, https://warontherocks.com/2023/08/you-go-to-war-with-the-industrial-base-you-have-not-the-industrial-base-you-want/.

a national policy on autonomous weapons systems. This should include a clear articulation of the Danish position on the precise threshold between legally unproblematic and problematic drone autonomy. Denmark must also, however, recognise the limits of debating the status of autonomous weapons through an exclusively legal lens. A comprehensive ethical framework is needed; one that takes seriously the direct and indirect moral challenges of the technology, especially in relation to civilian protection. Denmark has an opportunity and responsibility to lead, not as a military first-mover but rather as a voice of prudence, identifying overlooked risks and uncertainties, and better articulating the reach as well as the limitations of autonomous warfare.

7. **Help to foster military cooperation on drone and counter-drone operations in Europe.** One key takeaway from the Russo-Ukrainian War has been the need for a robust and capable defence industrial base in Europe. Thus far, this has primarily centred on the mass production of artillery shells and ammunition. This effort is important, but it must expand to include a comprehensive European drone and counter-drone strategy. Smaller European militaries, including Denmark, would benefit from pooling knowledge better on the experience and challenges regarding drone procurement, integration, and operations, allowing for easier and faster development in this vital security area. Collaboration on design and investment in mass-produced, small drone models and affordable counter-drone systems should be pursued at the NATO, EU, and inter-state levels. Opportunities for Nordic cooperation should also be explored where feasible.

Resumé og anbefalinger

Denne rapport beskriver effekterne og implikationerne af drone- og antidrone-brug i Rusland-Ukraine-krigen, samt hvordan kombattanter i fremtidig væbnet konflikt kan drage lære af erfaringerne fra denne krig. Det accelererende tempo i drone- og antidrone-innovation og den voksende vigtighed af begge i både defensive og offensive strategier for de ukrainske og russiske styrker gør det højst sandsynligt, at droner vil spille en fremtrædende rolle i fremtidig krigsførelse. Hvis danske beslutningstagere undervurderer denne rolle, kan de fremover risikere at stå dårligt rustet til at udnytte – og forsvare sig imod – bevæbnede droner. Overvurdering kan på den anden side føre til en forvrænget "teknooptimisme", der gør Forsvaret blindt for denne teknologis meget reelle grænser. Denne rapport hævder, at droner ikke er, og sandsynligvis aldrig vil blive, en let løsning på moderne krigs udfordringer. De kan ikke omvælte fundamentale ulemper på slagmarken som følge af dårlig logistik eller mangler, hvad angår styrkedesign, deployering eller kvalitet, og deres indbyggede begrænsninger kan ikke overkommes, men kun afbødes. Som Rusland-Ukraine-krigen tydeliggør, har dronen dog utvetydigt bevæget sig fra være et perifert stykke udstyr, til nu at fungere som en central teknologi i moderne krig mellem stater.

Denne bevægelse og de ændringer i moderne krigsførelse, som den har medført, fanges bedst i tre tendenser. For det første ændrer udbredelsen af droneteknologi sig hastigt: med hensyn til *kvantitet* med et stigende antal statslige udbydere, modtagere og tilgængelige teknologier; med hensyn til *kvalitet* med den hidtil usete, voksende rolle for den private og offentlige sektor; og *i dybden* med stater, der anerkender vigtigheden af både en indenlandsk industriel base og internationale handelsforbindelser for at opfylde de nuværende og fremtidige behov for drone- og antidrone-kapaciteter.

For det andet er brugen af droner på slagmarken under udvikling. Den mest dybtgående indvirkning kommer her ikke fra de avancerede

droner af høj militær kvalitet, der definerede krigen mod terror, men snarere de masseproducerede og masseudsendte små, billige kommercielle droner, der dominerer luftrummet over Ukraine. Deres omkostningseffektivitet og brugervenlighed, kombineret med deres evne til at forbedre rekognoscerings- og kampoperationer, muliggør og letter deres fremtidige integration på alle kommandoniveauer. Det gør det så meget mere vigtigt at anskaffe effektive, men billige antidrone-løsninger.

For det tredje driver krigen mellem Rusland og Ukraine hastige fremskridt inden for militær AI, hvilket inkluderer autonome droner. Da AI kan hjælpe med at overkomme fjendtlig *jamming* og øge hastigheden og dødeligheden af droner i kampoperationer, har autonome droner et stort militært potentiale, men de er også behæftet med betydelige tekniske, moralske, juridiske og strategiske udfordringer.

Denne rapport giver en detaljeret redegørelse for denne udvikling og formulerer et sæt anbefalinger, der vil sætte Danmark i stand til at navigere gennem et dronelandskab, der er under hastig og dybtgående forandring.

1. **Opdater det europæiske og det danske tankesæt om droner.** I årtier har den europæiske debat om droner været formet af de droneoperationer, der blev gennemført under den globale krig mod terror i 2000'erne og 2010'erne. Den danske debat har også lagt stor vægt på arktisk overvågning. Det primære fokus for begge disse anvendelser har været komplekse droner af høj militær kvalitet. Debatten har behov for en opdatering. Det nutidige dronelandskab har ændret sig radikalt, især i relation til bølgen af billige, kommercielle og meget alsidige droner, som erhverves og bruges i stor skala. Militære styrker skal forberede sig på at operere på fremtidige slagmarker, der er mættede med drone- og antidrone-teknologier. Dronernes nye plads i militære operationer nødvendiggør en lige så væsentlig ændring i den doktrinære planlægning.
2. **Beslut, hvorvidt og hvordan der skal anskaffes bevæbnede droner.** Hvis regeringen vælger at anskaffe bevæbnede droner, skal teknologien fremover integreres på alle niveauer af Forsvarets styrkedesign. Alene dronernes rekognosceringskapacitet vil gøre dette nødvendigt. Danske politikere må dog heller ikke overse, at droner trods al deres værdi er et additiv i forbindelse med krig – de vil supplere og forbedre eksisterende kapaciteter, men sjældent erstatte dem helt.

3. **Invester i antidrone-systemer.** Hvis det danske forsvar skal operere effektivt på fremtidige slagmarker, har det behov for betydelige investeringer i antidrone-teknologier, herunder elektronisk krigsførelse og luftforsvarssystemer. Ligesom med droner vil disse kapaciteter kræve tid, ressourcer og træning at opbygge, og Danmark skal arbejde for at finde den rette balance og acceptere de uundgåelige afvejninger mellem effektivitet, masse, skala og omkostninger. Det bedste antidrone-system for Danmark vil ikke nødvendigvis være det militært set mest slagkraftige på markedet – indkøb og udvikling af disse teknologier kræver en langsigtet cost-benefit-analyse. Men det kræver også ambitionen om og ressourcerne til at handle på området nu. Forsinkelser i indkøb af antidrone-systemer risikerer at gøre danske soldater faretruende udsatte på slagmarken.
4. **Gennemfør en undersøgelse af det aktuelle forhold mellem den danske droneindustri og Forsvaret.** Fremadrettet vil det logistiske pres for at opbygge og vedligeholde dronelagre have mere til fælles med skalaen for kugler og artillerigranater end den for kampvogne og fly. For at imødekomme hjemlige behov og få succes på det enorme internationale dronemarked har Danmark brug for fleksible og lydhøre bureaukratiske processer, innovativt *drive*, en kultur, der tillader eksperimenter på de strategiske og taktiske niveauer, samt stærke bånd mellem staten og droneindustrien. Ukraine udvikler og modificerer droner i et hurtigt tempo i et sparsomt reguleret miljø på grund af den eksistentielle trussel fra Rusland. Danmark skal overveje både muligheder og risici ved denne lettelse af reguleringsbyrden. Regeringens egen tilgang bør dog ikke afspejle Ukraines, men snarere dens egen interne vurdering af fremtidige militære krav og ansvar.
5. **Vurder, hvor sårbar Danmarks kritiske infrastruktur er over for droneangreb.** Danmark bør forberede sig på en fremtid, hvor terrorister og andre fjendtlige aktører har stadig større adgang til billige og effektive midler til at skade eller forstyrre samfundet. Dette understreger igen vigtigheden af omkostningseffektive antidrone-systemer. Jo mere avanceret et givet defensivt system er, jo dyrere er det sandsynligvis at udvikle, genforsyne og vedligeholde. Forsvar af kritisk infrastruktur vil, ligesom forsvar af militære kapaciteter, kræve økonomisk bæredygtighed.
6. **Udform en politik for udviklingen og brugen af autonome våben.** Danmark skal følge sine allierede, såsom Storbritannien og USA, og

udforme en national politik for autonome våbensystemer. Dette bør omfatte en klar italesættelse af Danmarks holdning til den præcise tærskel mellem juridisk uproblematisk og juridisk problematisk autonomi, hvad angår droner. Danmark skal dog også anerkende grænserne for at diskutere autonome våben ud fra et udelukkende juridisk perspektiv. Der er behov for en stærk etisk linje i politikken, som tager de direkte og indirekte moralske udfordringer ved teknologien alvorligt, især i forhold til civilbeskyttelse. Danmark har en mulighed og et ansvar for at lede, ikke som en militær first-mover, men snarere som en stærk stemme for forsigtighed, der søger at identificere oversete risici og usikkerheder og bedre formulere en vision for ikke kun rækkevidden af, men også grænserne for, autonom krigsførelse.

7. **Promover militært samarbejde om drone- og antidrone-operationer i Europa.** Et vigtigt aspekt i krigen mellem Rusland og Ukraine har været behovet for en robust og dygtig forsvarsindustriel base i Europa. Fokusset har i den kontekst primært været på masseproduktion af artillerigranater og anden ammunition. Den indsats er vigtig, men skal udvides til at inkludere en omfattende europæisk drone- og antidrone-strategi. Mindre europæiske væbnede styrker, herunder det danske forsvar, vil kunne drage fordel af at fokusere på at samle viden om erfaringer og udfordringer med droneanskaffelse, -integration og -operationer, hvilket vil muliggøre en lettere og hurtigere udvikling på dette vitale sikkerhedsområde. Samarbejde om design af og investering i små og masseproducerede dronemodeller samt omkostningseffektive antidrone-systemer bør forfølges i NATO og EU og på mellemstatsligt niveau. Mulighederne for nordisk samarbejde bør også undersøges, hvor det er muligt.

ACKNOWLEDGEMENTS

The authors are hugely grateful to Kristian Søby Kristensen, CMS colleagues, and the anonymous reviewer for constructive comments and feedback. We would also like to thank our interviewees for their important insights.

1

Introduction

A typical first-person view (FPV) drone weighs up to 1 kg, is capable of carrying a payload of up to 2.5 kg, can reach speeds of up to 150 km/h, and can be assembled for as little as $400.[2] Both Ukraine and Russia have utilised these drones extensively for two years to strike and destroy multi-million-dollar pieces of military hardware.[3] Mass-produced and mass-deployed drones such as the FPV are changing the character of war. It is imperative for states to recognise this and modify their security policy and military doctrine accordingly.

Wars are most often ruinous for those who wage them, and should be primarily understood as such. In most cases, the key lesson to be drawn from the experience of war is that all efforts should be expended to avoid it. For those who believe in the rare necessity of armed conflict, however, additional lessons must be sought out. The Russo-Ukrainian War has been instructive in these terms, providing important takeaways for decision makers on force design, shifting battlefield priorities, and emerging and evolving military technologies. This is especially true in relation to the use and countering of drones. 'Everyone is learning from the current events in Ukraine', announced U.S. Air Force Chief of Staff General Charles Q. Brown Jr.[4] The challenge, however, lies in identifying the right lessons and rejecting the wrong ones.

2. Unless otherwise indicated, all monetary amounts are in USD.
3. The Economist, "How Cheap Drones Are Transforming Warfare in Ukraine," February 5, 2024, https://www.economist.com/interactive/science-and-technology/2024/02/05/cheap-racing-drones-offer-precision-warfare-at-scale.
4. Cited in Kelly A. Grieco, "Airpower after Ukraine: The Future of Air Warfare," *Atlantic Council*, August 2 2023, https://www.atlanticcouncil.org/programs/scowcroft-center-

The ongoing armed conflict between Russia and Ukraine is no 'remote war'.[5] It is a large-scale, immensely costly, conventional conflict dominated tactically by artillery and strategically by the enduring threat of nuclear weapons. Drones have, however, shaped the character of the conflict to a significant degree. This report considers the impact and implications of drone and counter-drone use in Ukraine, and the lessons offered for future warfare in a global and Danish context.

Drones have the potential to significantly benefit the Danish military by offsetting numerical disadvantages on the battlefield; providing powerful reserves of logistical, reconnaissance, and firepower support; enhancing combat operations; and lowering the associated risks and costs of war. Even if Denmark resists procuring and using *armed* drones, a better understanding of how these weapons will be exploited and defended against in future conflict is essential. This report will help to empower Danish policymakers to formulate and maintain strategically sound and morally responsible governance over the future use of drone and counter-drone technologies.

1.1. Background and Research Questions

For as long as war has been fought, ranged technologies have been exploited to preserve the life of those who kill, enhance the vulnerability of those targeted, and provide a number of other battlefield advantages. Today, these technologies include drones. Drones are remotely piloted aircraft of varying size, controlled by an individual.[6] These aircraft, which can be armed or unarmed and serve a multitude of functions, range from tiny, off-the-shelf commercial models, to multi-ton military-grade models, such as the RQ-4 Global Hawk, the price tag of which exceeds $100m. Most drones serve either a collection (e.g., surveillance, recon-

for-strategy-and-security/forward-defense/airpower-after-ukraine/.

5. 'Remote warfare' refers to the growing preference, particularly among Western actors, for 'lower cost' military operations: direct or indirect support of local and regional partners, the use of private military contractors and Special Forces, and air power. Neil Renic, "Remote Warfare: Drivers, Limits, Challenges," in *Routledge Handbook of the Future of Warfare*, (Routledge, 2023), 190-201, p. 190.
6. This report focuses primarily on aerial drones, but land and maritime (surface and sub-surface) drones exist and have both played a role in the Russo-Ukrainian War.

naissance, targeting) or delivery (e.g., food, medicine, missiles, grenades) function – or both. Attack drones may be reusable or consumable – the former is an aircraft equipped with munitions and designed for multiple missions, whereas the latter (alternatively referred to as a loitering munition, kamikaze drone, or one-way attack drone) *is* a munition, and therefore expended on impact.[7] The sheer variety of drone technology applications and the relative ease with which certain models can be procured, modified, and operated underline the significant battlefield potential of this weaponry.

Before turning to Ukraine, it is important to clarify that drones are not a new technology. Models such as the 'Curtiss-Sperry Flying Bomb' and the 'Kettering Bug' were tested but not deployed in the early twentieth century.[8] The German V-weapon programme of World War II provides another early antecedent of the armed drone; ISR drones were used by the United States from 1964 onwards in Vietnam; and Israel successfully used drones in 1982 as electronic decoys against Syrian missile emplacements in the Beqaa Valley.[9]

Associated for decades with the counter-terrorism operations of the United States, France, and the United Kingdom, drones are increasingly favoured for their warfighting potential. In the 2020 Second Nagorno-Karabakh War, drones provided a significant battlefield advantage to Azerbaijani forces in terms of intelligence, surveillance and reconnaissance, and long-range strikes against Armenian air-defence systems and other high-value military assets. Armed drones have also featured in recent intra-state conflicts, including the Tigray War and Syrian civil war.

While drones are not a new technology, debate is ongoing over their value and limitations in armed conflict, the character and scale of their global proliferation, and the likely battlefield and regulatory implications of their increasing autonomy. These debates have intensified

7. For ease of language, this report will use the term 'drones' unless specifically referring to a 'loitering munition'.
8. Lee Pearson, "Developing the Flying Bomb." In Naval Aviation in World War I (Washington D.C., Chief of Naval Operations, 1969), 70-2; Lawrence Spinetta, "Secrets behind the Surprising Rise of Drones," June 20, 2019. http://www.historynet.com/the-rise-of-unmanned-aircraft.htm; Laurence R. Newcome, *Unmanned Aviation: A Brief History of Unmanned Vehicles* (Barnsley, Pen and Sword Aviation, 2004).
9. W. Seth Carus, "The Bekaa Valley Campaign," *The Washington Quarterly* 5, no. 4 (1982): 34-41.

with the Russo-Ukrainian War, a conflict shaped by the extensive use of drones. This report advances this debate by addressing the following questions:

1) What role have drones played in the Russo-Ukrainian War?
The report details the tactical uses, effectiveness, limitations, and counters to drones (both military-grade and commercial) in Ukraine. It also considers the impact of drones on the strategic and operational landscape of the conflict.

2) What lessons does the Russo-Ukrainian War provide for the future use of drone and counter-drone technologies in war?
The report evaluates both the proliferation trends that influence the development and use of drone and counter-drone technology and the integration of both aspects into future warfare. The report further clarifies the substantial and increasing role of artificial intelligence in drone warfare.

3) What lessons should Danish decision makers draw from the Russo-Ukrainian War to better understand, exploit, control, and counter drone technologies going forward?
The report details the degree to which Danish security strategy must adapt to reflect the changes in war triggered or intensified by innovations in drone technology.

Any forward-looking analysis of military technology, including drones, must work to reach the appropriate balance between under- and over-statement. If Danish policymakers underestimate the future role of drones, they may be left ill-equipped to adequately address the opportunities and challenges presented by the technology. The inverse, however, is just as problematic: Visions of future armed conflict exaggerating the war-winning potential of drones may blind us to the less exciting but still critical lessons relating to force design, employment, and quality; logistics; and ammunition supplies.

Danish policymakers must also recognise that war is riven with uncertainties, and early conventional wisdom on what an armed conflict heralds, overturns, transforms, or necessitates is very often wrong. Obtaining even roughly accurate lessons may take months, years, or decades. For this reason, this report should be understood as exploratory – the

focus is on highlighting trends and patterns in drone and counter-drone warfare rather than offering definitive takeaways.

1.2. Data Sources

One distinct feature of the Russo-Ukrainian War is the degree to which active combat has been recorded and disseminated through traditional and non-traditional sources, especially combat featuring drone attacks. This report reflects this new reality, combining careful study of peer-reviewed work and policy briefs with analysis of live footage and reporting. Studies of the latter require caution due to the widespread mistaken or deliberately misleading reporting on this conflict, including in relation to the use of drones.

The consulted material includes:

- Military and drone specialists at think tanks and non-governmental organisations, such as The International Institute for Strategic Studies, the RAND Corporation, the Council on Foreign Relations, Royal United Services Institute, and the ICRC.
- Magazines and news portals specialising in defence and military affairs: *Foreign Policy*, *War on the Rocks*, *BBC*, *The Economist*, *Defence News*, *Defence One*, *Wired*, *Task & Purpose*, *Foreign Affairs*, *The Washington Post*, *New York Times*, *The Atlantic*, and *Bulletin of the Atomic Scientists*.
- Reports and documents by state and international organisations: *European Defence Agency, European Aviation Safety Agency, the North Atlantic Treaty Organization, U.S. Department of Defense, Congressional Research Service, United States Marine Corps, UNODA, the British Army, Office of the Director of National Intelligence, Government of Denmark*, etc.
- Relevant academic journals, including *The Journal of the JAPCC, ICCT, Contemporary Security Policy,* and *Air & Space Operations Review*.
- Translated footage and analysis disseminated on blogs and social media, including Twitter (now *X*) and Telegram.

Alongside this material, two former drone operators were interviewed.[10] An interview was also conducted with a Danish drone industry representative from Odense Robotics, an organisation comprising most Danish drone manufacturers focusing on the promotion of common interests.

1.3. Outline of the Report

This report contains four sections. Chapter Two evaluates drone and counter-drone technology proliferation trends within and beyond Ukraine. The Russo-Ukrainian War has intensified the proliferation of drones, horizontally, with an increase in the number of state actors developing and receiving these technologies; and vertically, through a growth in non-state[11] and non-military (private and public) support streams. The implications of both are presented.

Chapter Three evaluates the battlefield uses, limitations, and counters to drones in the Russo-Ukrainian War. The use of drone technologies in this conflict, both military-grade and commercial, is unprecedented. As this section clarifies, however, the technology is by no means a 'silver-bullet'.

Chapter Four draws upon the Russo-Ukrainian War to detail the challenges and opportunities of autonomous warfare. This conflict is accelerating the development and normalisation of autonomous drones, a move that will have profound implications for the future practice and regulation of war.

The report concludes with a Conclusions and Recommendations section, offering lessons for Danish military and security policy makers in relation to drone technology.

10. Interview I was conducted with Martin Melia, a former British Army officer with over 25 years of experience in the Infantry and the ISR domain. He is currently the Head of Operational Services for Eagle Eye Innovations, a leading RPAS services company based in the UK. Interview II was conducted with Jakub Jajcay, a former officer in the Armed Forces of the Slovak Republic, where he served in a number of elite units. Jakub has also operated drones in the Russo-Ukrainian War as a volunteer for the Ukrainian military.
11. 'Non-state' can refer to several different actors, including civilians, international institutions and organisations, private companies, and military groups. This report focuses primarily on civilians and the private sector.

2

Drone Proliferation in and beyond Ukraine

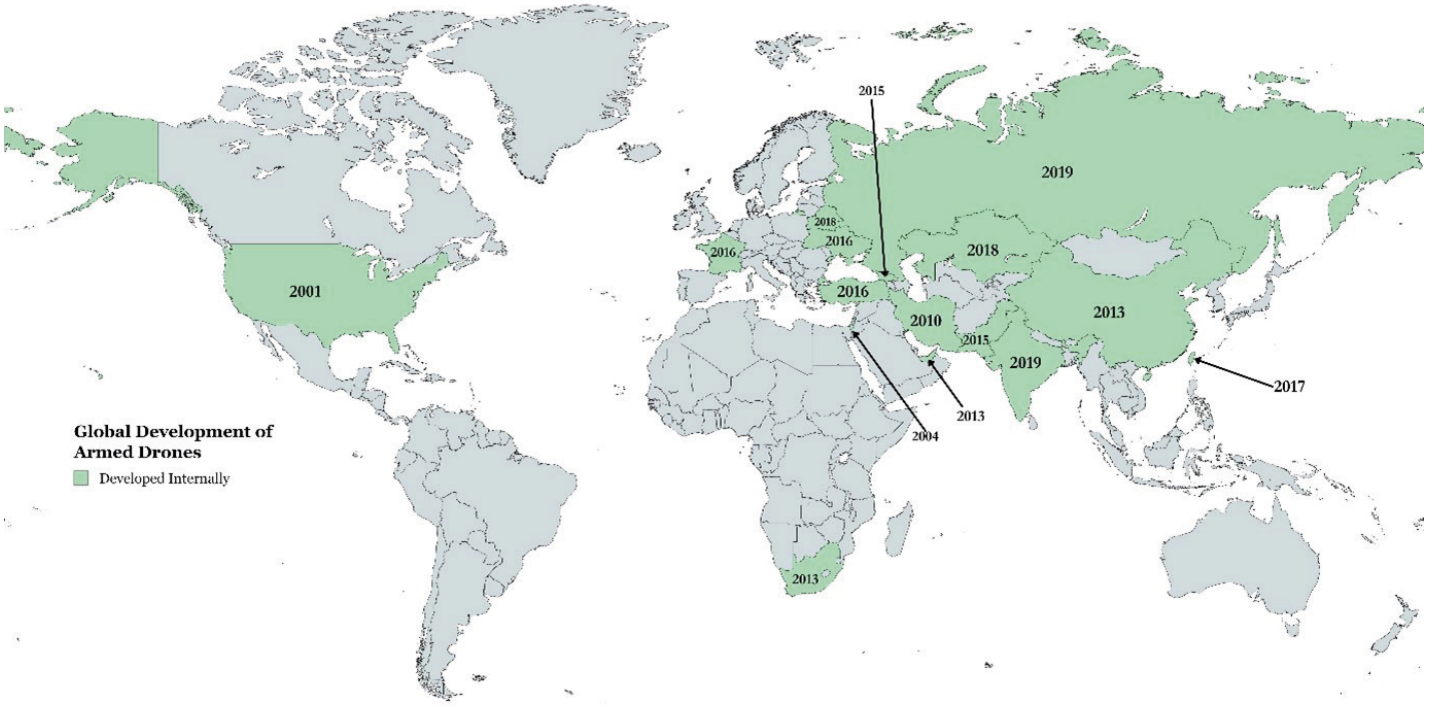
The Russo-Ukrainian War represents a critical juncture in drone technology development. While armed drones have been exploited on battlefields for decades, their use has never previously been so widespread, their cost at scale so low, and their sources of procurement so varied and differentiated. Drone technology proliferation trends are undergoing significant transformation in three ways: in *quantity*, with an increasing number of state providers, recipients, and available technologies; in *quality*, with the unprecedented and growing role of the private and public sectors; and in *depth*, with states recognising the importance of both a domestic industrial base and international trade links in meeting current and future needs.

2.1. Horizontal Drone Proliferation: Old and New State Actors – Producers and Recipients

The following figures highlight the steady growth over time in the global development and procurement of armed drones. This begins with American investment in MALE (medium altitude long-endurance) drones, followed by Chinese and Israeli programmes in the 2000s, and Iranian, Turkish, Russian, and French drone initiatives in the late 2010s.[12]

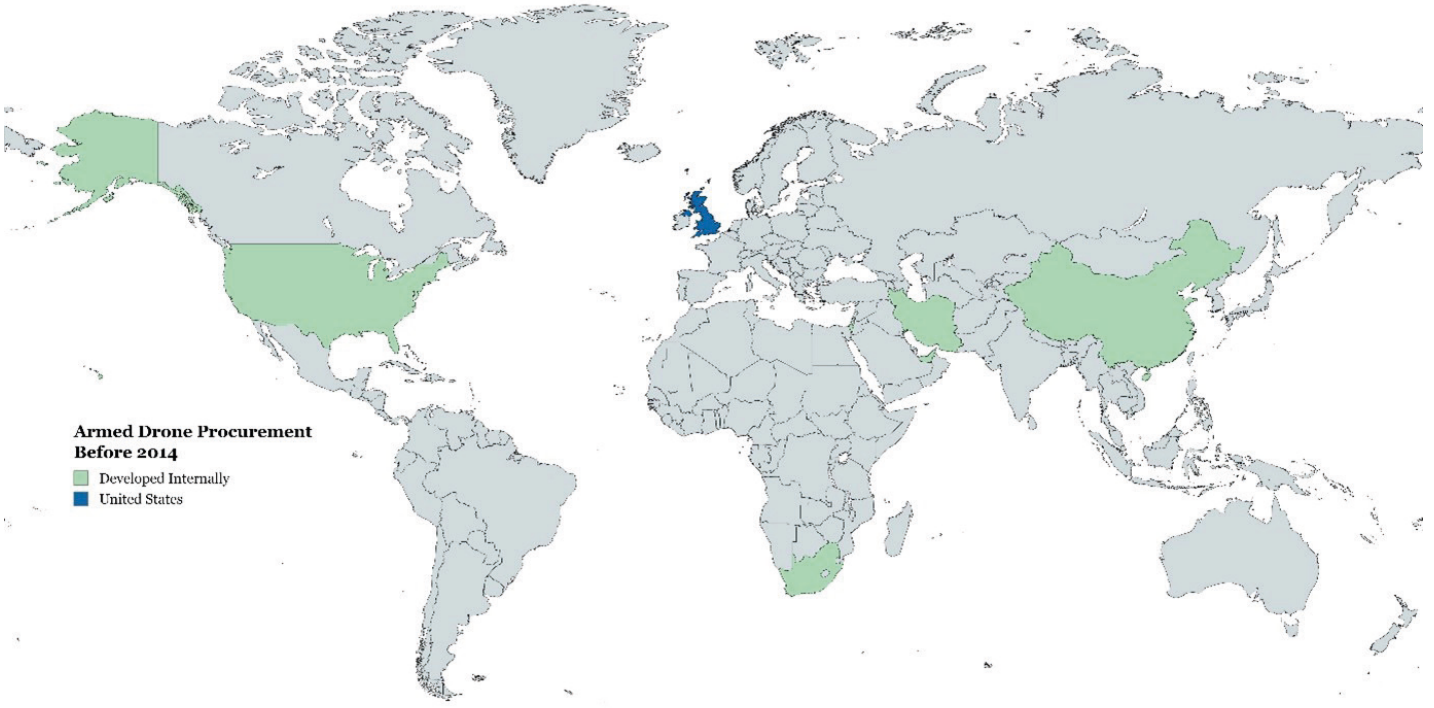
12. Chris Cole, "Rise of the Reapers: A Brief History of Drones," *Drone Wars UK*, October 6, 2014. https://dronewars.net/2014/10/06/rise-of-the-reapers-a-brief-history-of-drones/; Chris Cole, "Proliferation of Armed Drones Continuous Apace Resulting in Numerous Civilian Casualties," *Drone Wars UK*, February 13, 2024, https://dronewars.net/2024/02/13/proliferation-of-armed-drones-continues-apace-resulting-in-numerous-civilian-casualties/.

Figure 1. Global development of armed drones, 2001-22[13]



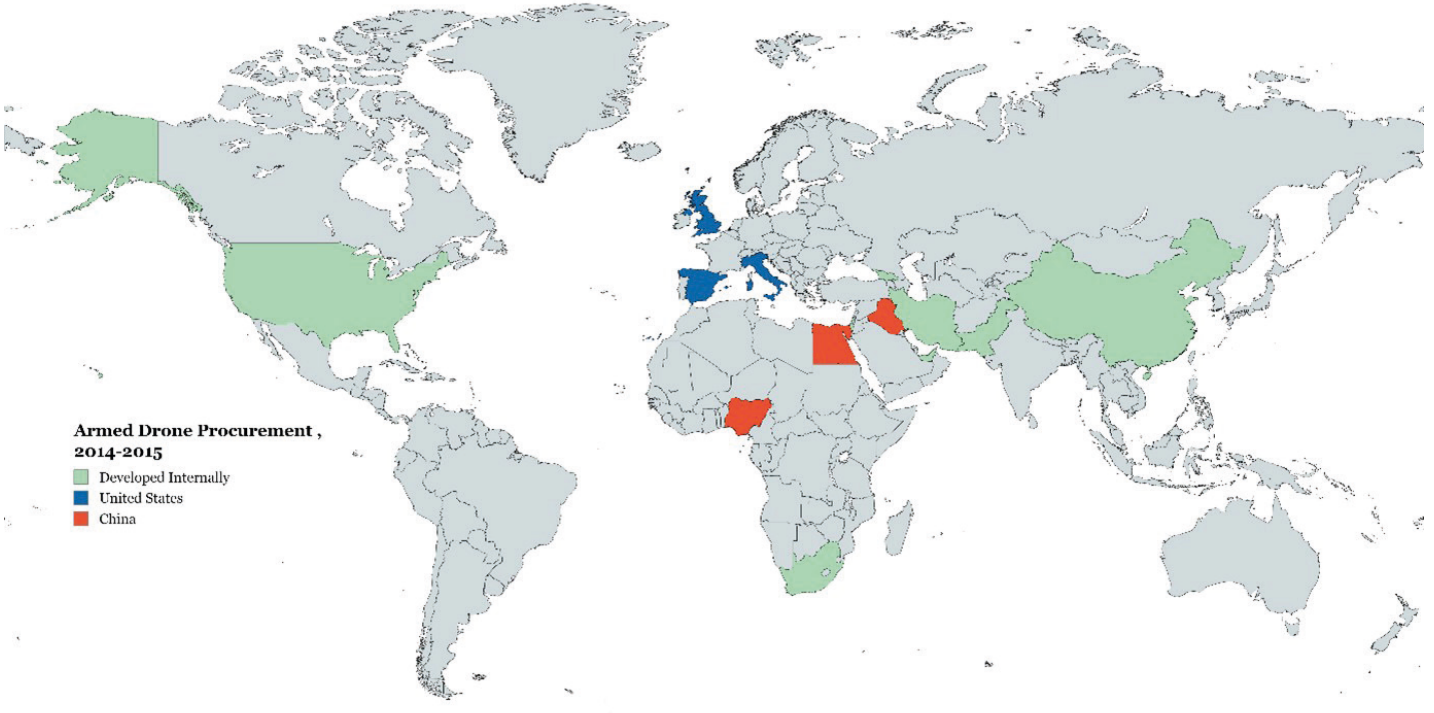
13. Peter Bergen, Melissa Salyk-Virk and David Sterman, "World of Drones," *New America*, July 30, 2022, https://www.newamerica.org/future-security/reports/world-drones/who-has-what-countries-with-armed-drones; Chris Cole, "Armed Drone Proliferation Update," *Drone Wars UK*, March 22, 2023, https://dronewars.net/2023/03/22/armed-drone-proliferation-update-march-23/.

Figure 2: Armed drone procurement before 2014[14]



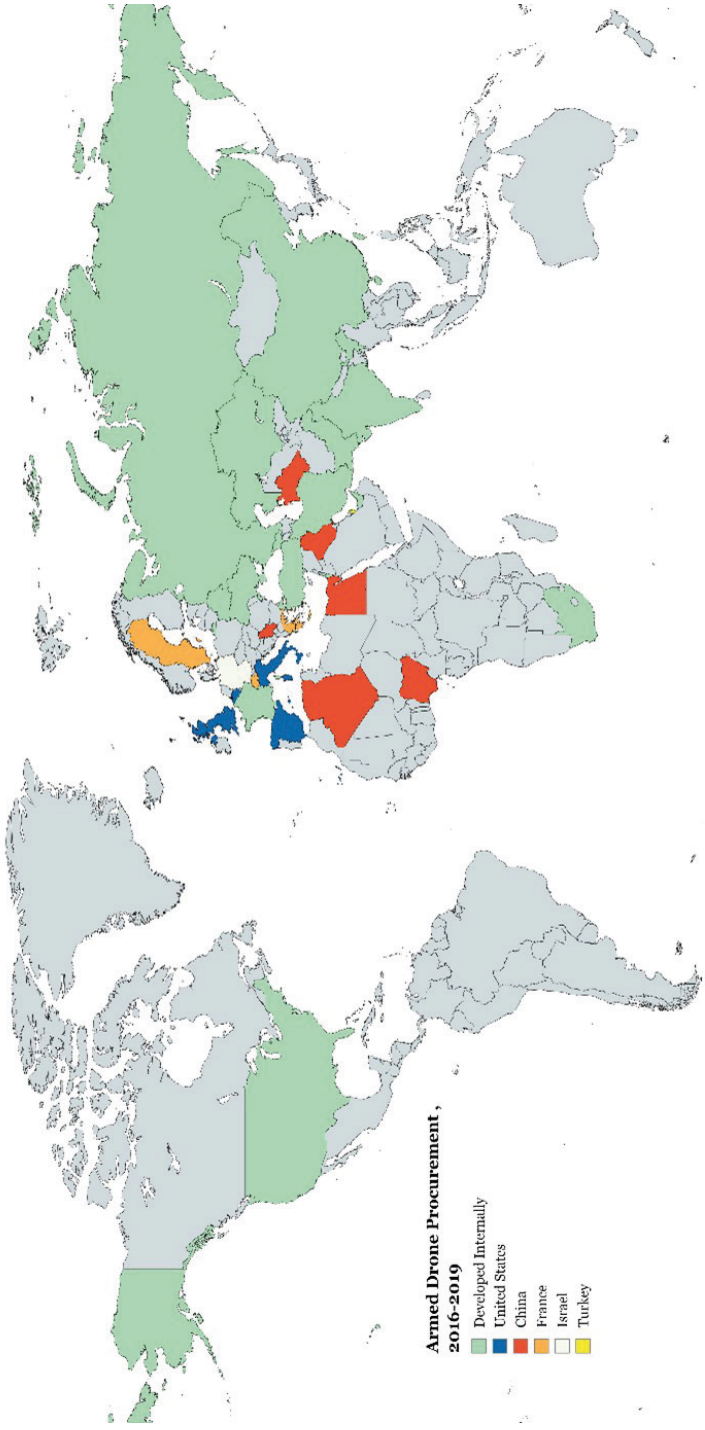
14. Bergen, Salyk-Virk, and Sterman, "World of Drones."

Figure 3: Armed drone procurement, 2014-15[15]



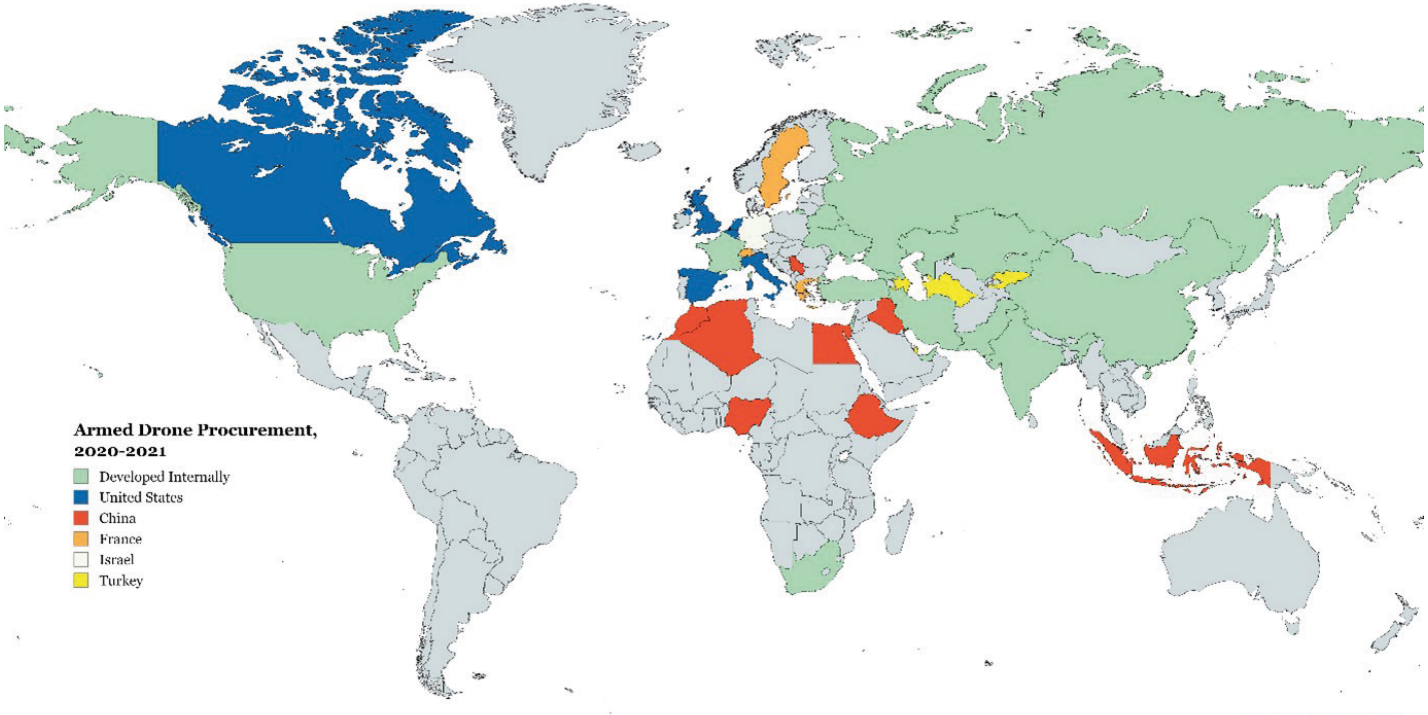
15. Ibid.

Figure 4: Armed drone procurement, 2016-19[16]



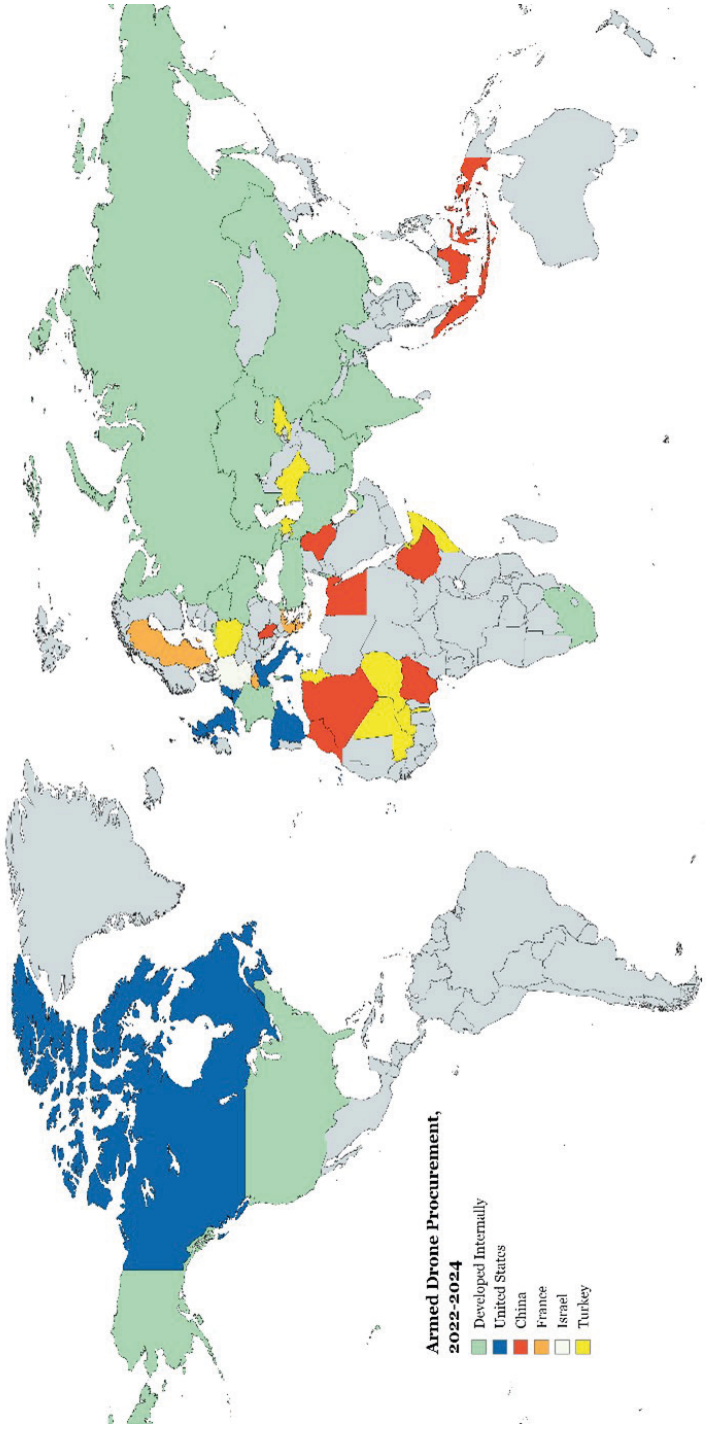
16. Ibid.

Figure 5: Armed drone procurement, 2020-21[17]



17. Ibid.

Figure 6: Armed drone procurement, 2022-24[18]



18. Ibid.

The Russo-Ukrainian War has accelerated the horizontal and vertical proliferation of drones. Horizontal proliferation refers to the spread of drone technologies to new state actors. For established drone powers (e.g., the United States, Israel), as well as emerging drone powers (e.g., China, Turkey, Iran), the conflict in Ukraine provides an opportunity to increase the accessibility and improve the image of this technology. Long associated with counter-terrorism and, more specifically, the legally and morally controversial practice of targeted killing, drones are increasingly seen as a legitimate and indispensable tool of inter-state war. The global drone market will be of increasing geopolitical significance, facilitating the creation, strengthening, and in some cases testing of alliance relationships.

The main provider of military support to Ukraine throughout the conflict has been the United States. The military component of this aid currently totals $43.85 billion and includes a range of drone technologies.[19] In April 2022, the U.S. Air Force revealed its newly developed Phoenix Ghost, a loitering munition that has now been delivered to Ukraine to aid in its defence.[20] With a 40 km range and 6-hour operating time, the Phoenix Ghost joins other U.S.-delivered loitering munitions, such as the Switchblade and ALTIUS-600, as well as surveillance drones, such as ScanEagle, Puma, JUMP, and Cyberlux.[21] Alongside loitering munitions and surveillance drones,[22] the United States is supplying counter-drone capabilities, such as the new VAMPIRE (Vehicle-Agnostic Modular Palletized ISR Rocket Equipment), an air defence system using small missiles to shoot enemy drones out of the sky.[23]

19. Kiel, "Ukraine Support Tracker," Institute for World Economy, December 7, 2023, https://www.ifw-kiel.de/topics/war-against-ukraine/ukraine-support-tracker/.
20. Jon Harper, "2022 in Review: Ukraine Serving as Proving Ground for New – and Sometimes Secretive – US Defense Tech," *Defence Scoop*, August 2 2023, https://defensescoop.com/2022/12/29/2022-in-review-ukraine-serving-as-proving-ground-for-new-and-sometimes-secretive-us-defense-tech/.
21. Jonathan Masters and Will Merrow, "How Much Aid has the U.S. Sent Ukraine? Here Are Six Charts," *Council on Foreign Relations*, August 3 2023, https://www.cfr.org/article/how-much-aid-has-us-sent-ukraine-here-are-six-charts.
22. This includes unmanned coastal defence vessels, likely to be used for surveillance, mine clearing, and targeting assistance.
23. Harper, "2022 in Review."

The supply of remote technologies by the United States to Ukraine has not been unlimited. Requests from Kyiv for larger armed drones, including the MQ-1C Gray Eagle, MQ-9A Reaper, and long-range weapons platforms, have been denied thus far. This is partly due to American concerns that the Multi-Spectral Targeting System (MSTS), which provides real-time intelligence, targeting, and tracking to its operators, will be captured and studied by Russia.[24] Other concerns include training and logistical challenges associated with the technology, questions over its potential vulnerability to Russian air-defence, and fears that these weapons may further escalate the conflict.[25] As this highlights, the U.S. provision of drone technologies to Ukraine is significant but still governed (and partly inhibited) by strategic-political concerns.[26]

Alongside the United States, Turkey has been an important provider of drones to Ukraine, particularly in relation to the Bayraktar TB2, a MALE combat drone purchased by Ukraine for $2 million. First rising to prominence in the Nagorno-Karabakh conflict, the drone seized global headlines early in the Russo-Ukrainian War with a lauded status that, in reality, vastly exceeded its actual military contribution.[27] Nevertheless, the Bayraktar's performance in Ukraine has seen global interest in the weapon rise significantly, especially from states that are unable to purchase drone technology from traditional providers, such as the United States and Israel.[28] Nine countries currently operate Turkish drones, with many more placing orders or expressing an interest in doing so.[29]

24. Alexander Ward and Lee Hudson, 2022, "Why the Gray Eagle Still Hasn't Landed in Ukraine," *Politico*, August 9 2022, https://www.politico.com/newsletters/national-security-daily/2022/08/09/why-the-gray-eagle-still-hasnt-landed-in-ukraine-00050499.
25. Mike Stone, "Ukraine Asks U.S. for Big Drones, Hoping to Overcome Opposition," *Reuters*, 3 August 2023, https://www.reuters.com/business/aerospace-defense/ukraine-asks-us-big-drones-hoping-overcome-opposition-2022-11-15/#:~:text=WASHINGTON%2C%20Nov%2014%20(Reuters),drones%20and%20attacks%20civilian%20infrastructure.
26. A broader concern relates to the ongoing political will of the United States in relation to the Ukrainian war effort. At the time of writing, U.S. President Biden has yet to pass a $110 billion package to Ukraine, Israel, and other allies.
27. Owing to its limited number (Ukraine received fifty of these models from Turkey) and growing vulnerability to Russian counter-drone techniques.
28. Dominika Kunertova, "The War in Ukraine Shows the Game-Changing Effect of Drones Depends on the Game," *Bulletin of Atomic Scientists* vol. 79, no. 2, (2023), https://www.tandfonline.com/doi/full/10.1080/00963402.2023.2178180.
29. Federico Borsari, "Turkey's Drone Diplomacy: Lessons for Europe," *European Council on Foreign Relations*, January 31 2022, https://ecfr.eu/article/turkeys-drone-diplomacy-

Such exports are a boost to the Turkish economy and represent an opportunity to enhance the nation's hard power and political influence internationally.[30]

Beyond the United States and Turkey, drone technologies have also featured in the military aid packages of other state supporters of Ukraine. Both Canada and the United Kingdom have sent or pledged attack drones to aid the Ukrainian war effort, with Canada sending 800 SkyRanger R70s. Recently, a British-Latvian-led coalition of NATO members began an initiative to 'scale up and streamline' the drone supply to Ukraine, committing to providing 'up to a million battlefield drones'.[31]

Military aid also includes counter-drone capabilities, such as drone jammers and air defence systems. These systems, which primarily take the form of ballistic or electronic defence, include Lithuanian 'Skywiper' jamming rifles, British 'Terrahawk Paladin' air defence platforms, Australian 'Slinger' cannons, Norwegian 'Cortex Typhoon' machine gun platforms, American 'VAMPIRE' rocket launchers, and Israeli 'Smartshooter' fire control systems.[32] Counter-drone aid has also been provided (or at least pledged) by countries such as Germany,[33] Czech Republic,[34]

lessons-for-europe/.

30. Stijn Mitzer and Joost Oliemans, "An International Export Success: Global Demand for Bayraktar Drones Reaches All Time High," *Oryx*, September 2, 2022, https://www.oryxspioenkop.com/2021/09/an-international-export-success-global.html; Jack Dutton, "Saudi Arabia Agrees to Produce Turkey's Baykar Drones," *Al-Monitor*, August 7, 2023, https://www.al-monitor.com/originals/2023/08/saudi-arabia-agrees-produce-turkeys-baykar-drones.
31. Mared Gwyn Jones, "UK and Latvia Lead Coalition to Provide Thousands of Drones for Ukraine," *Euronews*, February 15, 2024. https://www.euronews.com/my-europe/2024/02/15/uk-and-latvia-lead-coalition-to-provide-thousands-of-drones-to-ukraine.
32. Ethan Walton, "Here's the Counter-Drone Platforms Now Deployed in Ukraine," *C4ISRNET*, November 21, 2023. https://www.c4isrnet.com/opinion/2023/11/21/heres-the-counter-drone-platforms-now-deployed-in-ukraine/.
33. Bundesregierung, "Military Support for Ukraine," November 1, 2023, https://www.bundesregierung.de/breg-en/news/military-support-ukraine-2054992.
34. Government of the Czech Republic, "Czechia Sends Hundreds of Heavy Military Systems Worth Tens of Billions to Ukraine during the First Year of Russian Invasion," *Vlada*, February 23, 2023, https://www.vlada.cz/en/media-centrum/tiskove-zpravy/czechia-sends-hundreds-of-heavy-military-systems-worth-tens-of-billions-to-ukraine-during-the-first-year-of-russian-invasion-203252/.

Netherlands,[35] France, and Italy.[36] In an airspace increasingly saturated with Russian drones, these systems have been essential to defend Ukrainian units, cities, and critical infrastructure from attack.[37]

Western states have also benefitted from their provision of military aid, with the conflict seen as a laboratory and testing ground for drone warfare innovations. Influenced by the increasingly significant role of drones and counter-drones in Ukraine, Western actors are devoting considerable resources to drone capabilities,[38] a move that will shape global and regional military technology development, procurement, and proliferation going forward. Drones will be a fixture of future war – responsible state actors must reconcile themselves to this fact, and plan their defence procurement and regulatory strategies accordingly.

When tracking these developments, we cannot lose sight of the equally intense expansion of drone development and proliferation among non-Western actors, including Iran.[39] Prior to the conflict, Iran's primary drone customers were militias;[40] this has now changed with the Russian demand for large quantities of Iranian drones and loitering munitions. Just as with Western support for Ukraine, the Iranian drone build-up will have implications that go beyond this specific conflict. Iranian drones are increasing not only in number, but also sophistication and le-

35. Government of the Netherlands, "Dutch Aid for Ukraine: From Day to Day," November 6, 2023, https://www.government.nl/topics/russia-and-ukraine/dutch-aid-for-ukraine.
36. Permanent Mission of France to the United Nations in New York, "France Supports Ukraine in Exercising Its Right to Self-Defense," 12 September, 2023, https://onu.delegfrance.org/nouvelle-traduction-france-supports-ukraine-in-exercising-its-right-to-self; Le Monde, "France and Italy Will Send Ukraine MAMBA Missile Systems, Officials Say," *Le Monde*, February 3, 2023, https://www.lemonde.fr/en/international/article/2023/02/03/france-and-italy-will-send-ukraine-mamba-missile-systems-say-french-officials_6014333_4.html.
37. Kunertova, "Game-Changing."
38. For some examples, see Sebastian Sprenger, "Hungary Orders Hero Kamikaze Drones from Rheinmetall-UVision Venture," *Defense News*, July 20, 2023, https://www.defensenews.com/global/europe/2023/07/20/hungary-orders-hero-kamikaze-drones-from-rheinmetall-uvision-venture/, Elisabeth Gosselin-Malo and Vivienne Machi, "Greece Picks Safran's Patroller Drones as French Industry Deepens Ties," *Defense News*, June 23, 2023, https://www.defensenews.com/unmanned/2023/06/23/greece-picks-safrans-patroller-drones-as-french-industry-deepens-ties/, and Yimou Lee, James Pomfret, and David Lague, "Special Report-Inspired by Ukraine War, Taiwan Launches Drone Blitz to Counter China," *Reuters*, July 21, 2023, https://www.reuters.com/article/us-china-tech-taiwan-idUSL4N39714X.
39. The role of China as a major drone actor will be detailed in Section 2.3, which covers the private sector dimensions of drone proliferation.
40. Kunertova, "Game-Changing."

thality,[41] a development that concerns the United States and Europe. In response, we can expect Western actors to prioritise the production and export of low-cost defence systems able to counter the mass-produced drones directed by Iran, Iranian proxies, and other adversaries.[42]

This again speaks to the rapidly shifting international drone landscape. It is no longer helpful to think of drones as the expensive and exclusive tools of militarily advanced states. Their development and uses have undergone significant change; they are obtainable from a growing number of state and non-state providers and will be increasingly favoured in war, regardless of belligerent, region, or conflict type, as an effective and affordable battlefield capability. The same goes for the weapon systems designed to jam, shoot, and neutralise them.

2.2. The Growing Importance of a Domestic Drone Industry

As well as reaffirming the pivotal role of international military aid in large-scale conflict, the Russo-Ukrainian War has confirmed the importance and challenges of maintaining a domestic drone and counter-drone industry. 'Both sides are treating drones the same as artillery shells now', argues Chief Executive Cole Rosentreter from Pegasus, a Canadian drone maker; 'whoever has the logistical base to out-produce the other has a clear advantage on the battlefield'.[43]

Russia is a late starter to armed drones, with its first armed model, the Orion, entering service in late 2020. Throughout 2022, much of the focus was on the mixed Russian record in domestic drone production – a distribution of limited resources across too many projects and a preference for centralised control over the stimulation of private initi-

41. Nakissa Jahanbani, Muhammad Najjar, Benjamin Johnson, Caleb Benjamin, and Muhammad Al-Ubaydi, "Iranian Drone Proliferation Is Scaling up and Turning More Lethal," *War on the Rocks*, September 8, 2023, https://warontherocks.com/2023/09/iranian-drone-proliferation-is-scaling-up-and-turning-more-lethal/.
42. Ibid.
43. Cited in Paul Mozur, Aaron Krolik, and Keith Bradsher, "As War in Ukraine Grinds On, China Helps Refill Russian Drone Supplies." *The New York Times*, March 21, 2023, sec. Business. https://www.nytimes.com/2023/03/21/business/russia-china-drones-ukraine-war.html.

atives impeded the Russian efforts to boost drone production. 'Simply put', argues Russia expert Samuel Bendett, 'the Russian MoD [Ministry of Defence] remains a very large, bureaucratic, top-heavy and overburdened apparatus that takes a long while to move in the right direction'.[44] Constraints on the Russian industrial base from international sanctions and export controls further impaired the ability of the invading power to manufacture remote technologies at scale.[45] Russia is still lacking in all types of drones,[46] a problem that has sparked open complaints from Russian officials and military personnel.

The domestic Russian drone industry is strengthening, however. This has been enabled, firstly, by large-scale defence investment across the board; Russia's current military spending is more than twice its pre-war levels.[47] Secondly, while international sanctions have degraded indigenous Russian production, it has not halted it. A joint investigation between *RUSI*, *Reuters*, and *IStories* has found that the Russian military-affiliated manufacturer of the Orlan-10 combat drone has continued to secure Western manufactured components through illicit supply chains, enabling further investment in the weapon.[48]

Russia is hoping, through a billion-dollar weapons deal with Iran, to domestically produce 6,000 drones – variants of the Iranian Shahed-136 – by the summer of 2025.[49] By this same year, Russia is aiming for 30 per-

44. Cited in Sydney J. Freedberg Jr, "How Not to Innovate: Russia Plays Catch-up to Ukraine on Drones," *Breaking Defence*, May 30 2023, https://breakingdefense.com/2023/05/how-not-to-innovate-russia-plays-catch-up-to-ukraine-on-drones/.
45. Kunertova, "Game-Changing." Pavel Luzin, "Russian UAVs: What Has Gone Wrong," *The Jamestown Foundation*, November 11 2022. https://jamestown.org/program/russian-uavs-what-has-gone-wrong/.
46. Jeffrey A. Edmonds and Samuel Bendett, "Russia's Use of Uncrewed Systems in Ukraine," *CNA*, March 15, 2023, https://www.cna.org/reports/2023/03/Russian-Uncrewed-Systems-Ukraine.pdf.
47. Georgi Kantchev, "Russia's Economy Goes All in on War: Putin Aims to Outlast the West, Which Is Struggling to Supply Weapons and Ammunition to Ukraine," *The Wall Street Journal*, October 6, 2023, https://www.wsj.com/world/russia/putin-redirects-russias-economy-to-war-production-1e14265f.
48. James Byrne, Jack Watling, Justin Bronk, Gary Somerville, Joe Byrne, Jack Crawford, and Jane Baker, "The Orlan Complex," *RUSI*, December 15 2022. https://rusi.org/explore-our-research/publications/special-resources/orlan-complex-tracking-supply-chains-russias-most-successful-uav.
49. Dalton Bennett and Mary Ilyushina, "Inside the Russian Effort to Build 6,000 Attack Drones with Iran's Help," *The Washington Post*, August 17, 2023, https://www.washingtonpost.com/investigations/2023/08/17/russia-iran-drone-shahed-alabuga/?utm_cam-

cent of its total weapon structure to consist of robotic systems, including unmanned air and ground vehicles. Heavy investments are also planned to train the expertise to support this force restructuring.[50] While Russian outcomes will likely fall short of this ambition, these plans signal a long-term commitment to expanding the domestic manufacture of, and self-reliance on, drones.

Russia is also prioritising the domestic production of counter-drone equipment. Russia is currently relying on a large stockpile of Soviet-era electronic warfare (EW) technologies together with modern EW equipment that it has mass-produced since 2008.[51] Responding to battlefield demands, the Russian government has boasted of a 500% increase in EW equipment production in an 11-month period in 2022-23.[52] While such claims should be treated with caution, Russia has clearly prioritised the development and modernisation of its EW capabilities.[53]

Ukraine also provides lessons on the importance of domestic drone production in meeting the challenges of large-scale warfare. A *RUSI* Report from May 2023 estimated Ukrainian drone losses to be approximately 10,000 per month, largely as a consequence of potent Russian EW.[54] This loss rate places an immense burden on Ukrainian leaders to preserve and replenish remote technology stockpiles. In January 2023, it was reported that the Ukrainian military would spend nearly $550 million that year to produce 1-2 million drones. By July, the pledged figure had increased to over $1 billion. In February 2024, President Zelenskyy

paign=dfn-ebb&utm_medium=email&utm_source=sailthru&STOverlay=2002c2d9-c344-4bbb-8610-e5794efcfa7d.

50. Krystyna Marcinek and Eugeniu Han, "Russia's Asymmetric Response to 21st Century Strategic Competition: Robotization of the Armed Forces," *RAND*, March 12, 2023. https://www.rand.org/pubs/research_reports/RRA1233-5.html.
51. Duncan McCrory, "Electronic Warfare in Ukraine: Preliminary Lessons for NATO Air Power Capability Development," *The Journal of the JAPCC*, no. 36, Summer 2023, 69-74. https://www.japcc.org/wp-content/uploads/JAPCC_J36_screen.pdf.
52. The Russian Government, "Meeting of the Coordination Council on the Needs of the Russian Federation Armed Forces, Other Troops, Military Units and Bodies," December 5, 2023, http://government.ru/en/news/50324/.
53. Roger N. McDermott, "Russia's Electronic Warfare Capabilities to 2025," *International Centre for Defence and Security,*" September 2017, https://icds.ee/wp-content/uploads/2018/ICDS_Report_Russias_Electronic_Warfare_to_2025.pdf.
54. Jack Watling and Nick Reynolds, "Meatgrinder: Russian Tactics in the Second Year of its Invasion of Ukraine," *RUSI*, May 19, 2023, https://www.rusi.org/explore-our-research/publications/special-resources/meatgrinder-russian-tactics-second-year-its-invasion-ukraine.

created the Unmanned Systems Force, a separate branch of the Ukrainian armed forces devoted exclusively to drones.

Like the Russians, Ukraine also prioritises the development of counter-drone technology. Here, the emphasis is on technologies featuring hybrid elements of electronic and kinetic capability,[55] with Ukraine seeing this as a more cost-effective option in the short run than the large EW systems traditionally employed.[56] In a 2023 essay, former Ukrainian Commander-in-Chief Valerii Zaluzhny stressed the need for substantial Ukrainian investments to counter Russia's 'significant electronic warfare superiority'.[57]

When evaluating the impact of technology on the Russo-Ukrainian War, it can be tempting to pay disproportionate attention to the military value of particular weapons and weapons systems. In terms of actual battlefield effectiveness, however, it is the innovative drive and organisational capacity of those who develop and field such hardware that is typically more determinative. 'This is a 24/7 technology race', argues Ukrainian Deputy Prime Minister Mykhailo Fedorov; 'The challenge is that every product in every category must be changed daily to gain an advantage'.[58] To meet this challenge, Ukraine has encouraged a diversified (and in many cases bottom-up) approach to innovation:

> *Ukrainian conscripts have been able to use clusters of commercial and military technologies (interacting technologies like sensors, satellites,*

55. Examples include Lithuanian Skywiper EDM4S anti-drone rifles, the Australian Slinger anti-drone AA-systems, American VAMPIRE rocket systems, and Norwegian CORTEX Typhon anti-drone machine gun systems.
56. Defence Express, "What EW Systems and 'Drone Killers' Has Ukraine Received to Counter Lancets and Shahed-136 Combat UAVs?", November 24, 2023, https://en.defence-ua.com/weapon_and_tech/what_ew_systems_has_ukraine_received_to_counter_lancets_and_shahed_136_combat_uavs-8655.html.
57. Valery Zaluzhny, "Modern Positional Warfare and How to Win It," *UDC 355*, https://infographics.economist.com/2023/ExternalContent/ZALUZHNYI_FULL_VERSION.pdf. See also Clare Sebastian, "Ukraine Makes New Push to Defeat Russia's Electronic Warfare," *CNN*, November 29, 2023, https://edition.cnn.com/2023/11/29/europe/ukraine-russia-electronic-warfare-intl-cmd/index.html.
58. Cited in John Hudson and Kostiantyn Khudov, "The War in Ukraine Is Spurring a Revolution in Drone Warfare Using AI," *The Washington Post*, July 26, 2023, https://www.washingtonpost.com/world/2023/07/26/drones-ai-ukraine-war-innovation/.

machine learning, and quickly updateable software) to network, interact, and create dynamic systems much faster than Russian soldiers can.[59]

As this highlights, the warfighting of the future will increasingly depend on the effective fusion of state, private, and public efforts.

2.3. Vertical Drone Proliferation I: Private Actors Entering the Drone Space

Whereas horizontal proliferation refers to the spread of drone technologies to new state actors, vertical proliferation speaks to the introduction (or intensified role) of non-state actors.

The first of these is the private sector. The illegal Russian invasion of Ukraine has catalysed the first large-scale, high-intensity armed conflict in which both belligerents extensively deploy military and commercial drones. The private sector has played a key role in this transformation.

In contrast to Russia's top-down approach to drone capability development, Ukraine has sought to incentivise its private sector through a range of initiatives, including a policy allowing private companies to receive a larger profit margin on the drones they produce.[60] In April 2023, Ukraine launched the 'Brave1' portal to facilitate public-private innovation by providing a single place for directing Western resources. Ukraine has also encouraged private actors from European countries to establish drone production plants in the country.[61]

While Western private actors are growing in influence, Chinese companies continue to dominate the commercial dimension, particularly the manufacturer DJI. Although it has yet to supply military-grade models

59. Audrey Kurth Cronin, "Open Source Technology and Public-Private Innovation Are the Key to Ukraine's Strategic Resilience," *War on the Rocks*, August 25, 2023, https://warontherocks.com/2023/08/open-source-technology-and-public-private-innovation-are-the-key-to-ukraines-strategic-resilience/., emphasis in original.
60. Christiaan Triebert, Haley Willis, Yelyzaveta Kovtun, and Alexander Cardia. "Ukraine's Other Counteroffensive: Drone Attacks on Russian Soil." *The New York Times*, July 31, 2023, sec. World. https://www.nytimes.com/2023/07/31/world/europe/ukraine-drone-strikes-russia.html.
61. Elisabeth Gosselin-Malo, "Latvia's Atlas Dynamics to Open Drone Production Plant in Ukraine," *Defense News*, December 23, 2022, https://www.defensenews.com/unmanned/2022/12/23/latvias-atlas-dynamics-to-open-drone-production-plant-in-ukraine/.

to either Ukraine or Russia, Chinese drone companies have played a major role in the conflict. Small, versatile DJI drones have been exploited significantly by both parties to monitor and eliminate targets at reduced prices.[62]

In 2023, Ukrainian stockpiles were roughly equally split between domestic and foreign drones, the latter mostly comprised of DJI products.[63] This balance is shifting, however, with Ukrainian officials working to phase out Chinese consumer drones in favour of more professional, encrypted weapons platforms. The Ukrainian defence sector has been upgrading its counter-jamming capabilities, with companies like Himera Tech and Cosmolot producing new radio transmitters less vulnerable to Russian EW attacks.[64] American companies have also been invited to test drone equipment with counter-jamming properties on the battlefield.[65] The challenge for Ukraine lies in determining the appropriate cost-benefit balance, as some experts doubt the necessity of counter-jamming equipment for expendable drones deployed *én masse*.[66]

Russia has also benefited from the Chinese private sector. Nearly seventy Chinese companies have sold twenty-six brands of drones to Russia since the invasion began in February 2022. As noted earlier, however, questions remain concerning the efficiency of the Russian Ministry of Defence (MoD) in getting these smaller drones to front-line forces.[67]

Beyond China, the American private sector is also looking to involve itself in the Russo-Ukrainian War. U.S. defence contractors have spo-

62. The United States has made efforts to curtail this influence – DJI was blacklisted in 2020 by the U.S. Commerce Department, preventing American companies from selling the technology without explicit permission. https://www.nytimes.com/2023/03/21/business/russia-china-drones-ukraine-war.html?searchResultPosition=1.
63. Mozur, Krolik, and Bradsher, "Russian Drone Supplies."
64. Loyd Lee, "Ukraine Is Thinking More Like Silicon Valley to Defend Itself against Russian Electronic Warfare," *Business Insider*, November 20, 2023, https://www.businessinsider.com/ukraine-silicon-valley-start-up-combat-russian-electronic-warfare-jamming-2023-11?r=US&IR=T.
65. Ashish Dangwal, "Ukraine 'Invites' US Defense Firms to Test Their Weapons in Active Conflict Zone; Says Must Resist Russian EW Attacks," *The EurAsian Times*, March 6, 2023, https://www.eurasiantimes.com/ukraine-invites-us-defense-firms-to-test-their-weapon-systems/.
66. Sydney J. Friedberg Jr., "Dumb and Cheap: When Facing Electronic Warfare in Ukraine, Small Drones' Quantity Is Quality," *Breaking Defense*, June 13, 2023, https://breakingdefense.com/2023/06/dumb-and-cheap-when-facing-electronic-warfare-in-ukraine-small-drones-quantity-is-quality/.
67. Samuel Bendett, *Twitter*, April 6, 2023, https://twitter.com/sambendett/status/1643990213067411464.

ken openly about the significant profits expected from arming Ukraine through contracts with the U.S. government.[68] British companies have also benefited, using Ukrainian troop reports to improve their prototype drone and counter-drone products at a far greater pace than would otherwise be possible. 'It turns out', argues Minister of State for the Armed Forces of the United Kingdom James Heappey, 'that these companies that were patiently working away with the British Army, on a sort of five-year horizon, were accessing the latest information on Russian [electronic warfare] capabilities ... rapidly evolving their drone capability and getting it to the Ukrainians within five weeks'.[69] These benefits extend to military AI and autonomous weapons, with the Russo-Ukrainian War giving Western companies the opportunity to accelerate the battlefield testing of both.[70] These compressed development, testing, and improvement cycles within private industry will further advance the global proliferation of drone technology.

Looking to the situation in Denmark, several private actors have already been active on the drone market for an extended period. Companies such as Terma, Skywatch, MyDefense, Nordic Wing, Sensek, and UMAG Solutions currently produce and develop drone equipment and software for military contracts together with counter-drone equipment, such as jamming systems. To be clear, however, the focus here is on specialised drone products; there is currently no capacity to mass-produce drone or counter-drone technologies within Denmark.

A change in this status quo would be challenging for many reasons. The Danish Ministry of Defence Acquisition and Logistics Organisation (DALO),[71] the government body responsible for military contracting for the Danish Armed Forces, has made concerted efforts in recent

68. William D. Hartung, "How Pentagon Contractors Are Cashing in on the Ukraine Crisis," *Quincy Institute for Responsible Statecraft*, April 17, 2023. https://quincyinst.org/2022/04/17/how-pentagon-contractors-are-cashing-in-on-the-ukraine-crisis/.
69. Cited in Sam Skove, "UK Sees 'Incredible Acceleration' in Military Capabilities from Ukraine War," *Defence One*, November 14, 2023, https://www.defenseone.com/threats/2023/11/uk-gains-incredible-acceleration-military-capabilities-ukraine-war/392005/.
70. Melissa Heikkilä, "Why Business Is Booming for Military AI Startups," *MIT Technology Review*, July 7, 2023, https://www.technologyreview.com/2022/07/07/1055526/why-business-is-booming-for-military-ai-startups/; Vera Bergengruen, "How Tech Giants Turned Ukraine into an AI War Lab," February 8, 2024, https://time.com/6691662/ai-ukraine-war-palantir/.
71. Forsvarsministeriets Materiel- og Indkøbsstyrelse (FMI).

years to foster a deeper relationship with the Danish drone sector, seeking to boost domestic drone development. While this is seen as a marked improvement in terms of military-industry relationships by the Danish drone sector, the knowledge in the industry of the specific projects that DALO is looking to develop remains limited. The small size of the Danish market has incentivised these same companies to focus more on securing contracts from external actors.[72]

When exploring the potential need for and challenges facing domestic mass drone production, it is also worth mentioning the relative strictness of EU airspace laws, which regulate and limit product-testing possibilities. Preparing for a Specific Operations Risk Assessment (the EU regulation-based process for testing unmanned aircraft and assessing the general level of risk it brings to national airspace)[73] is a costly affair for smaller companies, which limits sector growth and diversification, as start-ups struggle to fund the testing costs.[74] Under the current regulatory landscape and with its relatively small size, the Danish drone sector will struggle to compete with other European industries to develop and deliver drones and counter-drone technologies to the Danish armed forces.

2.4. Vertical Drone Proliferation II: Public Actors Entering the Drone Space

In many ways, this is a volunteer drone war. Russia and Ukraine have both received large numbers of smaller, 'hobbyist' drones from their own populations. These commercial drones have been repurposed on the battlefield by civilians and combatants and are favoured for both their user-friendliness and low-cost.

One day into this war, Ukraine issued a mass social media appeal for hobbyist drones, a call enthusiastically answered by Ukrainian civil society. One of the largest Ukrainian volunteer organisations, 'Come

72. Interview III.
73. European Union Aviation Safety Agency, "Specific Operations Risk Assessment," February 1, 2024. https://www.easa.europa.eu/en/domains/civil-drones-rpas/specific-category-civil-drones/specific-operations-risk-assessment-sora.
74. Interview III.

Back Alive', raised over $115m in 2022 and was working in 2023 with 700 military units to provide a range of equipment, including drones.[75] Another Ukrainian initiative launched by President Zelenskyy, 'UNITED24', has worked to crowdfund the purchase of 10,000 one-way attack drones, to be purchased abroad and fitted with combat parts in Ukraine. As of October 2023, 5,000 units had already arrived.[76] According to one Ukrainian policymaker, this public campaign is intentionally disconnected from the military bureaucracy of the state, making it 'decentralised' and 'nimble'.[77]

'Dronations' are received through domestic crowdfunding campaigns, but also, in the case of Ukraine, via sympathetic neighbouring countries. To assist reconnaissance efforts, for example, a group of Finnish volunteers hand-delivered 140 DJI Mavic Mini drones to the Ukrainian military in early 2022. Launching a fundraising campaign, the group collected more than $57,000 to purchase the equipment.[78] Similar examples can be found elsewhere, including among the Baltic States.[79]

Russia's comparative isolation in this conflict has unsurprisingly limited its access to international drone donations. It does mirror Ukraine, however, in its growing focus on domestic charitable contributions, with direct appeals by Russian service members to the public for drone equipment.[80] Organisations such as Sudoplatov and the Arkhangelsk Group

75. Wendell Stevenson, "The 'Crazy Professors' Making Drones for Ukraine," *The Economist*, August 4, 2023, https://www.economist.com/1843/2023/08/04/the-crazy-professors-making-drones-for-ukraine.
76. Samuel Bendett, "The first 5,000+ FPV drones from Operation Unity are already in Ukraine. Next, the drones will be supplemented with Ukrainian-made munitions. There will be 10,000 FPV drones in total. These drones were purchased thanks to the joint collection of UNITED24, Povarnys Alive and monobank," *X*, October 11, 2023, https://twitter.com/sambendett/status/1712087538410660219.
77. J.K. Melchior, "Drones Are Giving Ukraine a Wartime Edge," *The Wall Street Journal*, February 23, 2023, https://www.wsj.com/articles/drones-are-giving-ukraine-a-wartime-edge-homemade-dji-china-russia-tanks-weaponry-invasion-civilian-volunteer-russian-occupation-5c0bab55.
78. Ishveena Singh, "Finnish Volunteers Deliver 140 DJI Mavic Mini Drones to Ukraine Military," *DroneDJ*, March 23, 2022, https://dronedj.com/2022/03/03/finland-140-dji-mini-drone-ukraine-military/.
79. Dominika Kunertova, "Game-Changing."
80. Faine Greenwood, "Drones in the Ukraine War: April 3 to April 11, 2022," *Little Flying Robots*, 12 April, 2022, https://faineg.substack.com/p/drones-in-the-ukraine-war-april-3rd?s=w; Inder Singh Bisht, "Russian Drone Plant Built with Iranian Help

produce FPV drones in the potential thousands, although Russian bureaucratic inefficiency and corruption sometimes complicate such efforts.[81]

These examples highlight an important dimension of current and future warfare: the erosion of centralised state control over drone supply. Going forward, remote technology acquisition will be more diversified, drawing on state and military sources, but also commercial and civilian actors. What will not change, however, is the importance of specialised training in extracting maximum benefit from these technologies. Both Ukraine and Russia have pressed those with drone industry and amateur experience to join the war effort in training, technical support, and operator roles. Racing drones, also known as First-Person View (FPV) drones, are faster and more manoeuvrable than the standard commercial quadcopters that essentially fly themselves. Success with FPVs is highly dependent on the 'dexterity and fast reflexes' of the user, and Ukrainian private schools are currently offering training courses for citizens with a pass rate of 60-70%.[82] Russia has similar programmes dedicated to training engineers, programmers, and drone instructors, but as already noted, these efforts have been marred by the ponderous and inefficient bureaucracy of the Russian military-industrial complex.

This civilian dimension also highlights an important difference between drone and counter-drone technology procurement. The diversification of drone supplies has been enabled by rapidly lowering costs and expanded commercial availability. This has yet to occur to the same degree with counter-drone equipment, which remains a (relatively) expensive and technologically complex battlefield resource. An important lesson from Ukraine is that the future of drone proliferation will not

Opens," *The Defense Post*, July 10, 2023, https://www.thedefensepost.com/2023/07/10/russian-drone-plant-iranian/?expand_article=1.

81. David Hambling, "Russian Volunteer Group Claims to Make 1,000 FPV Kamikaze Drones a Day," *Forbes Magazine,* December 5, 2023, https://www.forbes.com/sites/davidhambling/2023/12/05/russian-volunteer-group-making-a-thousand-fpv-kamikaze-drones-each-day/?sh=61cea19711ec.
82. The Economist, "How Could FPV Drones Change Warfare?", August 4, 2023, https://www.economist.com/the-economist-explains/2023/08/04/how-could-fpv-drones-change-warfare?utm_medium=social-media.content.np&utm_source=twitter&utm_campaign=editorial-social&utm_content=discovery.content.

only be more diversified than the past, but also more integrated, between state, commercial, and civilian streams:

> *The core theme of Ukraine's wartime innovation, apparent in robotic and autonomous systems (RAS), has been the close collaboration and communication between civilian developers and military end-users. This has enabled the free flow of feedback and iterative improvements to how the technology is used and designed.*[83]

R&D investment, domestic manufacturing capacity, and international supply links will be critical in producing and deploying drones at the scale and speed needed to confront and overcome the challenges of the battlefield. Just as important will be the quality of payloads and enabling technology, and the technical understanding and training to deploy these systems effectively. Neither drone infrastructure – material or intellectual – nor drone diversity can be secured overnight. States wanting to maximise their advantages over, and limit their vulnerabilities to, remote technologies in future warfare will need to invest the necessary resources early.

2.5. The Politics of Drone Proliferation

Moving forward, we are likely to face an international drone landscape of increased heterogeneity: more state developers and recipients; enhanced focus on domestic manufacturing; and an intensification of non-state supply streams – both public and private. This will change both the character of war and its geopolitics. The Russian procurement of Iranian weapons and subsequent strengthening of the strategic relationship between the two countries, for example, will have implications beyond this particular conflict.[84]

83. Julia Muravska, "Drones and Defence Innovation in Ukraine: Consolidating Wartime Ingenuity," *King's College London*, November 29, 2022, https://www.kcl.ac.uk/drones-and-defence-innovation-in-ukraine-consolidating-wartime-ingenuity.
84. Mohammad Eslami, "Iran's Drone Supply to Russia and Changing Dynamics of the Ukraine War," *Journal for Peace and Nuclear Disarmament*, November 20, 2022.

It is also worth observing how these developments are occurring within what remains a relatively unregulated space. The Missile Technology Control Regime (MTCR) defines armed drones as a missile technology, but its restrictive guidelines apply only to larger drones with a 300 km range and an explosive payload of at least 500 kg. This leaves the large and rapidly growing category of smaller armed drones in a regulatory grey zone:

> *Most armed drones used in the war in Ukraine fly right under the MTCR's radar. The loitering munitions seen on the battlefield in Ukraine are smaller than a cruise missile, can carry three or more times the explosive payload of an artillery shell, and use commercially available engines. Efforts to control the export of armed drones thus lag considerably behind the realities on the battlefield. In addition, local drone manufacturing workshops will make monitoring and controlling arms exports increasingly difficult.*[85]

An absence of international controls, increasing affordability, and the perception of high battlefield utility guarantee that drones will become an essential tool of future warfare. In focusing on the opportunities this will bring, however, we must not lose sight of the equally significant vulnerabilities. Though not a major focus of this report, armed non-state actors also recognise the potential of this technology. Violent groups such as Hezbollah, Hamas, the Houthi Movement, Islamic State, and the Kurdish Workers' Party (PKK) have established drone programmes (some for more than a decade) and a demonstrated willingness to innovate technically and tactically in this area.[86] The Hamas attack on Israel on 7 October 2023, for example, utilised drones in first-wave attacks against Israeli cameras, communications, and observation towers.[87]

85. Kunertova, "Game-Changing."
86. Yannick Veilleux-Lepage and Emil Archambaut, "A Comparative Study of Non-State Violent Drone Use in the Middle East," *ICCT*, December 9, 2022, https://www.icct.nl/index.php/publication/comparative-study-non-state-violent-drone-use-middle-east.
87. Kerry Chávez and Ori Swed, "How Hamas Innovated with Drones to Operate like an Army," *Bulletin of the Atomic Scientists*, November 1, 2023, https://thebulletin.org/2023/11/how-hamas-innovated-with-drones-to-operate-like-an-army/.

Although Denmark's recent focus has understandably shifted to inter-state war and great power contestation, it cannot lose sight of the changes in state vs. non-state warfare created or intensified by the global diffusion of drones. Drone technology proliferation is a double-edged sword – it presents opportunities for Denmark to field a more cost-effective and lethal force while also magnifying dangers from both state and non-state adversaries. These opportunities and dangers will be considered in greater length in the next section, which evaluates the battlefield use, limitations, and military implications of drones in Ukraine.

3

The Battlefield Use of Drone Technologies

The Russo-Ukrainian War has sparked wide-ranging debate on the extent to which drone technologies will transform warfighting. For some, this transformation is seismic, with comparisons drawn to the Revolution in Military Affairs of the 1990s.[88] This is counterbalanced by more cautious evaluations framing drone advancements as a tool to incrementally enhance rather than fundamentally restructure the battlefield.[89]

By themselves, drones are not a war-winning technology, nor are they ever likely to be. They will always retain a set of vulnerabilities, and there will always remain tasks that they cannot execute and goals they cannot accomplish. They will, however, play an increasingly important role in warfare, regardless of the theatre and scale of operations. Both sides have heavily integrated drones into this war, and they are significantly shaping the battlefield in terms of the range, intensity, effectiveness, and

88. Bill Edwards, "Revolution in Military Affairs vs Military Revolution: The Emergence of Drones and Robotics as a driver in Societal Change", *Small Wars Journal*, November 11, 2022, https://smallwarsjournal.com/jrnl/art/revolution-military-affairs-vs-military-revolution-emergence-drones-and-robotics-driver; Bradley Perrett, "Small, cheap and numerous: a military revolution is upon us", *The Strategist*, January 22, 2024, https://www.aspistrategist.org.au/small-cheap-and-numerous-a-military-revolution-is-upon-us/.

89. Stacie Pettyjohn, "Evolution Not Revolution: Drone Warfare in Russia's 2022 Invasion of Ukraine," *Centre for New American Security*, February 2024, https://s3.us-east-1.amazonaws.com/files.cnas.org/documents/CNAS-Report-Defense-Ukraine-Drones-Final.pdf; Antonio Calcara et al., "Air Defence and the Limits of Drone Technology," *Lawfare*, July 31, 2022. https://www.lawfaremedia.org/article/air-defense-and-limits-drone-technology.

cost of violence. In each stage of this war – the early rapid Russian offensives; Ukrainian counter-offensives; and attritional fighting along the country-long front line – drones have created opportunities, offset limitations, and helped to exploit adversary vulnerabilities. That they have done so even as both sides race to nullify their effects with counter-drone investments speaks to their significant battlefield value.

This expanded role is here to stay. Thus, the most basic observation is that drone and counter-drone technologies can no longer be treated as peripheral features of war. Both will play a central role in the warfighting of the future, and the concepts and practices of Danish military planners must adjust accordingly.

The following section overviews the drone and counter-drone systems in use by Ukraine and Russia, details the variety of ways these systems have been utilised on the battlefield, and evaluates the broader implications of these battlefield effects for current and future warfighting.

3.1. Tactical Uses in Ukraine

The Russo-Ukrainian War has waged long enough for observable trends in drone use to emerge. Whereas the initial stages of this conflict were dominated by advanced MALE drones utilised as fire support platforms, we have seen the emphasis increasingly shift to smaller, less expensive, more numerous, and more disposable drones. It is in this shift that we witness the most profound changes to war. We are now confronting a battlefield increasingly saturated with sensors, jammers, and fire support systems, where massive numbers of drones are integrated into all levels of military forces and employed for a variety of purposes, including battlefield surveillance, and the targeting and elimination of high-value targets.[90]

90. Dominika Kunertova, "Drones Have Boots: Learning from Russia's War in Ukraine," *Contemporary Security Policy* 44, no. 4 (October 4, 2023). https://www.tandfonline.com/doi/full/10.1080/13523260.2023.2262792; Yaroslav Trofimov, "Drones Everywhere: How the Technological Revolution on Ukraine Battlefields Is Reshaping Modern Warfare," *The Wall Street Journal*, September 28, 2023. https://www.wsj.com/world/drones-everywhere-how-the-technological-revolution-on-ukraine-battlefields-is-reshaping-modern-warfare-bf5d531b.

Textbox 1: Force multiplication vs. media amplification

When debating battlefield uses of drones, it is important to differentiate between force multiplication and media amplification. In warfare, force multiplication can be defined as the ability of a technology or doctrine to make the force already at your disposal more effective, enabling greater results with the same amount of labour and equipment.

Media amplification relates to the exposure drawn by a particular drone attack. How large is the audience? How significant the propagandistic effect? What impact, if any, does viewership have on user and adversary morale? The fact that drone attacks are recorded and disseminated to an unprecedented degree speaks to their profound media amplification effects. It is important, however, to resist the temptation to conflate this with direct battlefield performance. Although they often impact one another, force multiplication and media amplification are distinct, and excessive focus on the visceral spectacle of drones should not lead to exaggerated assessments of their battlefield efficacy.

Intelligence, Surveillance and Reconnaissance Missions

Intelligence, Surveillance, and Reconnaissance (ISR) missions constitute the primary area of use for drones in the Russo-Ukrainian War, with both sides employing this technology to gain a better understanding of enemy positions, reserves, capacities, and movements.[91] In terms of integration, Ukraine has prioritised drone availability, with most units now enjoying access to drones in some capacity.[92] This has been used to great effect. Drone ISR missions were key to identifying weak points in the Russian lines near Kharkiv, which helped to facilitate the successful Ukrainian counter-offensive of 2022 that recaptured hundreds of square kilometres of lost territory.[93]

91. Evidence of this emphasis on ISR can be seen in Annex I of this report.
92. Elias Yusif, "Drone Warfare in Ukraine: Understanding the Landscape," *Stimson*, June 30, 2022. https://www.stimson.org/2022/drone-warfare-in-ukraine-understanding-the-landscape/.
93. Isabell Khurshuydan et al., "Inside the Ukrainian Counteroffensive That Shocked Putin and Reshaped the War," *The Washington Post*, December 29, 2022. https://www.washingtonpost.

On the tactical level, the Ukrainian army favours squads of drone operators, often working alone or in pairs, concealed in forests or other rough terrain, where they can launch ISR missions with small Mavic-drones. These can remain aloft for 45 minutes and have a 30 km range, making them well suited to surveilling the battlefield quickly.[94] These drones have significantly enhanced the level of mission autonomy of Ukrainian combat units. Empowered with real-time information via overhead drones, Ukrainian forces can assess rapidly evolving battlefield circumstances and respond accordingly at a pace that far exceeds equivalent forces structured around a more 'Soviet-style' central command mind-set, where the individual commander receives orders from superiors:

> *[T]hat kind of [Soviet] legacy mind-set is very much micromanagement all the way down the chain. Unless you're in the Special Forces domain, it's really kind of like: you're waiting for orders, you're waiting for orders ... You know you will stay there and get shelled on and die – unless I tell you not to. As opposed to: here's the objective, here's how you communicate with everyone else in the battle space. This is how we're going to enable your own situational awareness, which is the critical piece ... I would say that drones are pushing conventional forces into the space previously occupied by Special Forces.*[95]

While this more flexible and responsive approach does not eliminate the fog of war, it does enhance the capacity of Ukrainian forces to navigate it.[96] The tactical importance of these drone operators is well known to the Russian army, who prioritise their elimination whenever they are found. As one Ukrainian soldier stated:

com/world/2022/12/29/ukraine-offensive-kharkiv-kherson-donetsk/.

94. Tim Lister et al., "The Enemy Is Always Looking for Us': Hidden in the Forest, Ukraine's Drone Operators Are Crucial to the Eastern Battle," *CNN World*, January 30, 2023. https://edition.cnn.com/2023/01/30/europe/ukraine-drone-operators-forest-kreminna-intl-cmd/index.html.
95. Interview I.
96. Jack Detsch, "How Ukraine Learned to Fight" *Foreign Policy*, March 1, 2023. https://foreignpolicy.com/2023/03/01/how-ukraine-learned-to-fight/.

> *At the moment, 'drone operator' is one of the most dangerous jobs. The enemy knows we are the eyes of our army. As soon as they locate a drone operator, they use all kinds of weaponry: barrel artillery, MLRS, tanks.*[97]

Russian forces have also integrated drones into their offensive and defensive reconnaissance, preferring, where possible, to use this technology to identify enemy positions rather than exposing more valuable infantry units, armoured personnel carriers, or tanks to Ukrainian fire. During Russian offensives, there will be an estimated 25-50 drones in-use along any given 10 km stretch of active front line, even when Russian infantry-based reconnaissance companies are out in force.[98] The Russians mainly utilise the Orlan-10 drone for these missions, though many other smaller drone types are also used.[99] Once ISR drones have identified enemy targets, they relay the information to attack drones, which strike, clearing the way for military vehicles to conduct ground assaults through minefields.[100]

The ISR capability of drones is a key element in combined arms warfare, given their ability to provide large-scale sensor coverage and multiplied firepower at a relatively low cost.[101] This is further demonstrated by the growing reliance on drones for forward observation and fire coordination.

97. Ibid.
98. Watling and Reynolds "Russian Tactics."
99. Federico Borsari, "Assessing Drone Operations in Ukraine: Trends and Implications," *Orion Policy Institute*, July 19, 2022. https://www.orionpolicy.org/orionforum/110/assessing-drone-operations-in-ukraine-trends-and-implications.
100. Eric Schmitt, "Ukraine Is Losing the Drone War: How Kyiv Can Close the Innovation Gap with Russia," *Foreign Affairs*, January 22, 2024. https://www.foreignaffairs.com/ukraine/ukraine-losing-drone-war-eric-schmidt.
101. Modern combined arms warfare, i.e., the integration of different combat arms (infantry, armour, etc.) to achieve mutually complementary battlefield effects, is a fast-moving arena in large part defined by the 'hider-finder'-dynamic, as both attackers and defenders constantly strive to detect enemy actions whilst concealing their own. Tom Simoens, "Combined Arms Warfare As the Key to Success on the Contemporary Battlefield?" *The Defence Horizon*, December 1, 2022. https://www.thedefencehorizon.org/post/combined-arms-warfare-success-battlefield.

Forward Observing and Fire Coordination

One key battlefield development in the Russo-Ukrainian War is the significant upgrade that can be observed in the tempo of offensive action. Central to this for the Ukrainian side has been their embrace of AI-enabled geolocation software, such as 'Metal' and 'Delta'.[102] These programs have been utilised to collect and analyse vast volumes of battlefield data to aid decision-making and enhance tactical and strategic advantage.[103] This includes an integration of target and object recognition with satellite imagery, and analysis of open-source data (including social media content), video footage, and ground-level photos, to identify Russian forces, weapons, and movements in real time.[104]

Drones are a critical element in this increasingly networked mode of warfare. Small consumer drones, outfitted with cameras (often infrared[105]) have been used extensively for forward observation, identifying enemy targets and directing artillery fire against them. Reports indicate that approximately 86% of Ukrainian targets are identified via drone ISR missions, underlining their critical importance as artillery spotters.[106] Artillery shells typically must land within two meters of an enemy trench to collapse it, and these smaller drones have been essential in providing the necessary precision to ensure such strikes. These same drones have allowed for radical improvements in the speed of this targeting process. For Ukraine, it is estimated that drones have reduced the time needed to initiate artillery bombardments from 20-30 minutes to 3-5 minutes.[107]

For Russia, artillery remains the pre-eminent arm of their military and is the key shaping factor of the battlefield at large. Organised into artillery brigades available as offensive or defensive fire support on the front lines, Russian forces generally prefer to remain mobile in the face of possible Ukrainian counter-artillery. Of special importance to Rus-

102. The specific role of autonomous drones in this conflict will be detailed in the next chapter.
103. Samuel Bendett, "Roles and Implications of AI in the Russian-Ukrainian Conflict," *Russia Matters*, July 20 2023. https://www.russiamatters.org/analysis/roles-and-implications-ai-russian-ukrainian-conflict.
104. Ibid; Cronin, "Strategic Resilience."
105. Danielle Gagne, "Stemming the Tide of Destruction: How Drones Are Saving Lives in Ukraine," *Drone Network News*, April 25, 2022. https://volatusaerospace.com/drone_network_news/how-drones-in-ukraine-save-lives/.
106. Ibid.
107. Watling and Reynolds, "Russian Tactics."

sian doctrine is the so-called Reconnaissance-Fire System, an artillery doctrine developed by the Soviet military favouring the tightest possible communications connection between spotters and shooters.[108] Russian efforts at networked warfare have started more slowly but are improving as drones and artillery batteries are better integrated. Just as with Ukraine, these benefits can be observed in the speeding up of Russian kill-chains: the structure of attack by which belligerents find, fix, track, target, engage, and assess targets:

> *In the first six months of the war, Russian artillery units that had their own drones, rather than relying on those from headquarters, could strike targets within three to five minutes of detecting them. Those without drones took around half an hour – with lower accuracy.*[109]

Combat Missions

Drones take on a number of different roles in combat missions: from ambushes and suicide strikes to munitions delivery. Offensively, they help to identify and eliminate human and material targets, including high-value enemy targets such as artillery, troop transport and infantry vehicles, anti-aircraft batteries, and ammunition trucks. Outside these frontline strikes, drones have also been widely used in deep strike operations to eliminate enemy military targets (and civilian targets in Russia's case).[110]

108. Rosoboronexport, "Strelets (index 83t215i): Reconnaissance, Control and Communications Complex." https://roe.ru/eng/catalog/land-forces/military-communications-equipment-and-automated-control-systems/automated-control-systems/strelets/; Sam Cranny-Evans, "Russia's Artillery War in Ukraine: Challenges and Innovations," *RUSI*, August 9, 2023. https://rusi.org/explore-our-research/publications/commentary/russias-artillery-war-ukraine-challenges-and-innovations.
109. Joshi Shashank, "The War in Ukraine Shows How Technology Is Changing the Battlefield," *The Economist*, July 3, 2023. https://www.economist.com/special-report/2023/07/03/the-war-in-ukraine-shows-how-technology-is-changing-the-battlefield.
110. Ukrainian models used include the Bayraktar TB2 and the UJ26 Beaver. Ragip Soylu, "Ukrainian TB2 Bayraktar Drone 'Bombed Oil Depots Deep inside Russia'," *Middle East Eye*, April 27, 2022, https://www.middleeasteye.net/news/russia-ukraine-tb2-bayraktar-drones-said-bombed-oil-depots; Global Defence Corp, "Ukraine Started Mass Producing UJ-26 Beaver Deep Strike Kamikaze Drones," January 11, 2024, https://www.globaldefensecorp.com/2024/01/11/ukraine-started-mass-producing-uj-26-beaver-deep-strike-kamikaze-drones/.

Larger military-grade drones (e.g., Bayraktar TB2s) rose to prominence early in the conflict as one of the most effective and hardest-hitting weapons available to Ukraine, destroying Russian missile launch sites, logistical depots, routes and convoys, as well as assisting in the sinking of the Black Sea Fleet flagship, the *Moskva*.[111] The effectiveness of these deep strikes was at times profound, with a lone Bayraktar TB2 at one point igniting 10,000 tonnes of fuel in Byransk, 150 km from the frontline.[112] More broadly, the Bayraktar can be credited with playing an important role in slowing the initial Russian advance through targeted strikes, reconnaissance, and logistical disruption.[113] Subsequent improvements in Russian air defence, however, have now nullified many of the advantages provided by the slower, low-flying, radio-reliant Bayraktar,[114] again highlighting the pivotal role of counter-drone jamming and weapons platforms in this conflict.

In terms of combat operations, the emphasis in the Russo-Ukrainian War has now mostly shifted from larger, more expensive military-grade drones such as the Bayraktar, to smaller, cheaper commercial drones. The cost-effectiveness and ease of use of these drones has allowed the Ukrainian military to integrate them at all levels of command. These drones include the DJI Mavic, a commercially available quadcopter used to strike Russian units, supply depots, command centres, and critical infrastructure.[115]

The extension of action further beyond the ranges of the Ukrainian and Russian frontlines is partly due to the heavy presence of counter-drone systems on the front, leaving rear areas more vulnerable to

111. Margarita Konaev, "Tomorrow's Technology in Today's War: The Use of AI and Autonomous Technologies in the War in Ukraine and Implications for Strategic Stability," *CNA*, September 2023: pp. 9. https://www.cna.org/reports/2023/10/Use-of-AI-and-Autonomous-Technologies-in-the-War-in-Ukraine.pdf.
112. Soylou, "Ukranian TB2 Bayraktar."
113. Gay Mortimer, "The History and Effectiveness of the Bayraktar TB2 Drone in Ukraine," *Middle East Eye*, June 26, 2023. https://www.suasnews.com/2023/06/the-history-and-effectiveness-of-the-bayraktar-tb2-drone-in-ukraine/.
114. Alia Shoaib, "Why Ukraine Is Able to Embarrass Russia's Air Defense Systems, among the Most Advanced in the World, with Small Drones," *Business Insider*, September 2, 2023. https://www.businessinsider.com/russia-ukraine-war-advanced-air-defenses-failed-drone-strikes-2023-9?r=US&IR=T.
115. Jared Keller, "Ukrainian Drones Are Making Life Hell for Russian Troops in Crimea," *Task & Purpose*, December 15, 2022. https://taskandpurpose.com/news/ukrainian-drones-crimea-warfare/.

attack.[116] There is an interplay here, with deeper strikes forcing the reallocation of counter-drone systems away from the frontlines, leaving critical areas more exposed.[117] In January 2024, Ukraine exploited these vulnerabilities by targeting oil and gas refineries deep within Russia, striking targets up to 900 km away in locations next to major Russian cities, such as St. Petersburg and Moscow.[118] These attacks were likely carried out by smaller drones (relative to the Bayraktar), underlining how far-ranging the strike power of these cheaper models has become.

Ukraine is now looking to develop larger FPV drones with secure software features, allowing them to drop mortar rounds at less risk of Russian hacking.[119] These enhancements will likely be limited, however. A major advantage of smaller drones is not their survivability, but their cost-effectiveness:

> *You have to think of drones as expendable material ... [in] the NATO militaries I'm familiar with, drones are this expensive, high-end piece of equipment that you have to sign for and request ... it's usually only certain people that are allowed to use it, and you have to get past that mind-set. You have to be, like, we have this drone, it's probably going to last a week, and then we have to get another one. We have to be resigned in advance to the fact that we're going to lose this $4,000 piece of equipment.*[120]

As a relatively inexpensive piece of disposable hardware, the effectiveness of smaller drones can be profound. FPV drones, some costing only a few hundred dollars, have eliminated tanks, including the Russian T90M,

116. Peter Dickinson, "Ukraine Needs Urgent Air Defence Aid as Putin Launches Bombing Campaign", Atlantic Council, January 2, 2024, https://www.atlanticcouncil.org/blogs/ukrainealert/ukraine-needs-urgent-air-defense-aid-as-putin-launches-bombing-campaign/.
117. Daniel Byman, "Are Ukraine's Airstrikes in Russia Effective?", *Foreign Policy*, October 4, 2023, https://foreignpolicy.com/2023/10/04/ukraines-airstrikes-inside-russia-moscow-drones-war-strategy/.
118. Reuters, "Russian Oil Facilities Hit by Drone Attacks, Fires," *Reuters*, January 29, 2024. https://www.reuters.com/markets/commodities/russian-oil-facilities-hit-by-drone-attacks-fires-2024-01-29/.
119. Faine Greenwood, "The Drone War in Ukraine Is Cheap, Deadly and Made in China," *Foreign Policy*, February 16, 2023. https://foreignpolicy.com/2023/02/16/ukraine-russia-war-drone-warfare-china/.
120. Interview II.

valued at up to $4.5 million.[121] In one instance, a Ukrainian unit was estimated to expend $100,000 worth of drone octocopters to eliminate $40 million worth of Russian material in just over one month.[122] High-value Ukrainian equipment, such as the Leopard-2 tank, have also been targeted and eliminated by Russian Lancet one-way attack drones costing a fraction of the price.[123]

Russia's own deep strikes have heavily emphasised civilian targeting. Throughout the conflict, Russia has conducted terror bombing against government buildings, humanitarian aid depots, energy grids, hospitals, etc. in large cities such as Kiev,[124] Lviv,[125] and Odesa.[126] These attacks have mostly utilised the Iranian Shahed-131 and 136 one-way attack drones,[127] which can be deployed in swarms and have a launch range of approximately 900 km for the lighter 131-variant, and between 1,000-2,000 km for the heavier 136-variant.[128] Costing as little as

121. Ryan Pickrell, "Top Tanks Worth Millions and Other Expensive Heavy Armor Are Being Hunted in Ukraine by Cheap Exploding Drones Worth Only a Few Hundred Bucks," *Business Insider*, August 8, 2023, https://www.businessinsider.com/ukraine-war-top-tanks-taken-out-by-cheap-hobby-drones-2023-8?r=US&IR=T.
122. Natalie Musumeci, "Ukraine Is Using $100,000 Octocopter Drones to Destroy Russian Tanks and Artillery Worth Millions, Even in the Dead of Night, Operator Says," *Business Insider*, October 6, 2023, https://www.businessinsider.com/ukraine-using-octocopter-drones-to-destroy-russian-tanks-2023-10.
123. Ellie Cook, "From Abrams to Leopards: The Cost of Western Tanks Being Sent to Ukraine," *Newsweek*, January 26, 2023, https://www.newsweek.com/cost-western-battle-tanks-m1-abrams-leopard-2-challenger-2-1776725; David Axe, "The Russians Reportedly Knocked out Two More Ukrainian Leopard 2 Tanks. That's Five Leopard 2 Losses in a Week," *Forbes*, October 28, 2023, https://www.forbes.com/sites/davidaxe/2023/10/28/the-russians-reportedly-knocked-out-two-more-ukrainian-leopard-2-tanks-thats-five-leopard-2-losses-in-a-week/?sh=1576602f1926.
124. Ted Regencia, et al., "Russia-Ukraine War Updates: Moscow, Kyiv TTrade Drone Attacks," *Al Jazeera*, September 26, 2023. https://www.aljazeera.com/news/liveblog/2023/9/26/russia-ukraine-war-live-several-dead-in-air-strikes-on-odesa.
125. Illia Novikov, "Russian Drone Attack on a City in Western Ukraine Sparks an Inferno at a Warehouse and Kills 1," *AP News*, September 19, 2023. https://apnews.com/article/russia-ukraine-war-drone-attacks-lviv-warehouse-fire-1e7471f82a847d7f2933007d92812389.
126. Al Jazeera, "Russian Drone Raid Kills 1 in Ukraine's Odesa, Kyiv Repels Missile Attack," *Al Jazeera*, September 6, 2023. https://www.aljazeera.com/news/2023/9/6/russian-drone-raid-kills-1-in-ukraines-odesa-kyiv-repels-missile-attack.
127. Conflict Armament Research, "Documenting the Domestic Russian Variant of the Shahed UAV," August 2023. https://storymaps.arcgis.com/stories/d3be20c31acd4112b0aecece5b2a283c.
128. Uzi Rubin, "Russia's Iranian-made UAV's: A Technical Profile," *RUSI*, January 13, 2023. https://www.rusi.org/explore-our-research/publications/commentary/russias-iranian-made-

$20,000 for the 131-variant, Shaheds are a far cheaper tool for this type of attritional bombing than cruise missiles.[129]

The impact of Russia's drone-based civilian bombing has been mixed – while the attacks have forced Ukraine to divert critical air-defence resources from the conflict theatre to cities, there is a high interception percentage, limiting the overall damage inflicted. Furthermore, just as with most other historical antecedents of terror bombing, this campaign of indiscriminate violence[130] has yet to meaningfully undermine the morale of Ukrainian defenders.

While most of the focus in this report is on aerial drones, it is important to reiterate that the value of this technology cluster extends beyond the air domain. The Russian Black Sea Navy anchored in the Black Sea and at Sevastopol on Crimea has suffered attacks from both airborne and seaborne Ukrainian drones. The sinking of the *Moskva* in April 2022 by Ukrainian drones[131] and the later attack on the port of Sevastopol in October that same year[132] further demonstrated the effectiveness of drones in the maritime domain. In both instances, drones were instrumental in the attacks, either through reconnaissance or directly as kamikaze weapons.

Psychological Effects

Both sides in this conflict have leveraged the psychological value of drones. This value is two-fold: first, the use of drones to generate pervasive dread in both the military and civilian spaces by instilling a sense of permanent vulnerability; and, second, the use of drones in 'shaping

uavs-technical-profile.

129. Associated Press, "How Russia Is Using Iranian Killer Drones to Spread Terror in Ukraine," *PBS News Hour*, October 17, 2022. https://www.pbs.org/newshour/world/how-russia-is-using-iranian-killer-drones-to-spread-terror-in-ukraine.
130. Ukraine has used drones, including autonomous variants, to produce photo and video documentation of Russian battlefield misconduct. United States Agency for International Development, "USAID Delivers Skydio Autonomous Camera Drones to Ukraine to Document War Crimes," July 23 2023, https://www.usaid.gov/news-information/press-releases/jul-27-2023-usaid-delivers-skydio-autonomous-camera-drones-ukraine-document-war-crimes.
131. Ken Dilanian et al., "U.S. Intel Helped Ukraine Sink Russian Flagship Moskva, Officials Say," *NBC News*, May 5, 2022. https://www.nbcnews.com/politics/national-security/us-intel-helped-ukraine-sink-russian-flagship-moskva-officials-say-rcna27559.
132. Alison Bath, "Ukrainian Drone Attack Could Be Precursor to New Maritime Fight in War with Russia," *Stars and Stripes*, November 07, 2022. https://www.stripes.com/theaters/europe/2022-11-07/russia-ukraine-drone-7957977.html.

missions' designed to lure enemies into disadvantageous positions or to over-respond to feinting attacks.

Psychologically, the constant presence of drones helps to elevate an already stressful frontline environment. The presence of a drone in the sky and accompanying buzzing of drone rotors can signal a number of deadly events for soldiers, including an imminent artillery barrage, a kamikaze attack, or a later offensive.[133] The intensifying focus on adequate counter-drone platforms can thus be seen as an attempt to not only physically shield combatants but also to create 'safe(er) zones' for frontline soldiers, potentially diminishing the psychological effect of the constant drone threat.[134]

Both tactically and strategically, drones have the potential to degrade combatant and unit morale, especially among forces already lacking in purpose and *esprit de corps*:[135]

> *And it will start to happen, particularly on conscripts or younger soldiers, who will find themselves in those positions. It will have that grating psychological effect that's going to push them more towards a defensive than an offensive mind-set ... And I'd say that what we should be doing is going beyond the ISR element and the kinetic strike element and explore more deliberate ways to use this capability in the psychological or influence activity domains. Because it will naturally have that effect anyway.*[136]

In the Ukrainian case, the psychological effects of drones have now extended to deep-strike operations, against Russian supply depots, convoys, and even Moscow itself. These strikes firstly work to materially degrade the Russian war effort. This now includes sustained drone attacks against Russian energy infrastructure, with the intention of crippling the industry that provides the overwhelming majority of Russian export

133. Adam Lowther and Mahube E. Siddiki, "Combat Drones in Ukraine," *Air & Space Operations Review* 1, no. 4, Winter 2022: pp. 13. https://www.airuniversity.af.edu/Portals/10/ASOR/Journals/Volume-1_Number-4/Lowther.pdf.
134. Romean Olearchyk, "Military Briefing: Russia Has the Upper Hand in Electronic Warfare with Ukraine," *Financial Times*, January 7, 2024. https://www.ft.com/content/a477d3f1-8c7e-4520-83b0-572ad674c28e; Byman, "Ukraine's Airstrikes."
135. Interview I.
136. Ibid.

earnings.[137] These attacks also work to frame the conflict for two different media spheres, demonstrating the ability of Ukraine to penetrate Russian air defences for Western audiences, while also illustrating to the Russian population and elites that their country is in fact engaged in war, and not merely a localised territorial 'special operation'.

Drones fulfil a growing number of important battlefield roles in Ukraine. Moving forward, militaries will increase their reliance on this technology for a range of tasks, including ISR, combat, and the shaping of enemy conduct and attitudes. Drones will, however, retain a set of limitations, especially as counter-drone capabilities inevitably improve.

3.2. Drone Limitations and Countermeasures

At the time of writing, a five-month Ukrainian counteroffensive is concluding. Ukraine did not secure its initial stated goals of liberating large amounts of territory from Russian forces, including the cities of Tokmak and Melitopol. Speaking in late 2023 on the counteroffensive, former Ukrainian Commander-in-Chief General Valerii Zaluzhny conceded that 'there will most likely be no deep and beautiful breakthrough ... The simple fact is that we see everything the enemy is doing and they see everything we are doing'.[138] This speaks to the growing importance of drones as a defensive tool, helping to identify and target concentrations of attacking forces. It also reinforces the limitations of drones as a 'game changer' – there is no easy way to overcome heavily embedded defence; no technological silver bullet to guarantee victory.

The Limitations of Drones

Drones will feature heavily in future war: to surveil the battlefield, identify and exploit enemy vulnerabilities, map lines, disrupt logistics, and strike targets. But the fundamentals of defence (e.g., deep lines of earth-

137. Luke Harding and Pjotr Sauer, "Ukraine Levels up the Fight with Drone Strikes Deep into Russia," *The Guardian*, January 27, 2024. https://www.theguardian.com/world/2024/jan/27/ukraine-levels-up-the-fight-with-drone-strikes-deep-into-russia.
138. The Economist, "Ukraine's Commander-In-Chief on the Breakthrough He Needs to Beat Russia," November 1, 2023, https://www.economist.com/europe/2023/11/01/ukraines-commander-in-chief-on-the-breakthrough-he-needs-to-beat-russia.

works, trenches, minefields) will still prove a formidable check against offensive manoeuvre, as reinforced by the inability of drones to prevent this war from transforming into an attritional slog.[139] The battlefield value of drones is therefore best understood as *additive*. Drones have enabled more effective and precise uses of force and widened the tactical and operational scope of those who possess them, but they are not determinative unto themselves, nor can they wholly replace traditional hardware, such as artillery.

The difficulties facing both Russia and Ukraine to perfect combined arms warfare further reveal the limitations of drones. As seen in the initial drive for Kyiv, Russian drones could not compensate for the poor interoperability between air and land forces, the lack of coordination between Russian tank columns, and inaccurate Russian data regarding battlefield conditions.[140] Thanks to combat experience, deliveries of equipment, and Western training, Ukraine has enjoyed greater success adapting to combined arms offensives. Nevertheless, there have still been serious difficulties shifting from traditional Soviet models of military organisation to those favoured by NATO and the United States.[141] While this remains the case, Ukraine will fail to fully capitalise on the offensive opportunities afforded by drones.

139. Stephen Biddle, "Ukraine and the Future of Offensive Maneuver," *War on the Rocks*, November 22, 2022. https://warontherocks.com/2022/11/ukraine-and-the-future-of-offensive-maneuver/.

140. Rosling Walker, "An Evaluation of the Russian Arrangement of Military Operations during the First Phase of the Russo-Ukrainian War," *The Forge*, 2022. https://theforge.defence.gov.au/war-college-papers-2022/evaluation-russian-arrangement-military-operations-during-first-phase-russo-ukrainian-war; Amos C. Foxm "Reflections on Russia's 2022: Invasion of Ukraine Combined Arms Warfare, the Battalion Tactical Group and Wars in a Fishbowl," *AUSA*, September 29, 2022. https://www.ausa.org/publications/reflections-russias-2022-invasion-ukraine-combined-arms-warfare-battalion-tactical.

141. Jeff Jager, "Challenges of Mechanized and Combined Arms Warfare: Lessons for Ukraine from Syria and Iraq," *Middle East Institute*, February 22, 2023. https://www.mei.edu/publications/challenges-mechanized-and-combined-arms-warfare-lessons-ukraine-syria-and-iraq; Alexander Borodikin, "'A Defeat for Russia Is Not a Victory for Ukraine': An Interview with Military Analyst Michael Kofman," *Mediazona*, May 12, 2023. https://en.zona.media/article/2023/05/12/KofmanMichael; Erik Kramer and Paul Schneider, "What the Ukrainian Armed Forces Need to Do to Win," *War on the Rocks*, June 2, 2023. https://warontherocks.com/2023/06/what-the-ukrainian-armed-forces-need-to-do-to-win/; Eric Schmitt and Helene Cooper, "Ukrainian Troops Trained by the West Stumble in Battle," *The New York Times*, August 2, 2023. https://www.nytimes.com/2023/08/02/us/politics/ukraine-troops-counteroffensive-training.html.

It is also worth recognising that drones are only as good as the infrastructure, expertise, and add-ons that undergird their use. With a loss rate estimated at 10,000 per month on the Ukrainian side, a major limitation related to this technology is the challenge of mass production and procurement. Failure to replenish stockpiles will erode the battlefield value of drones. Of further relevance, while many commercially available hobbyist drones are favoured for their ease of use, not all models are as quickly mastered. Military-grade drones, and even smaller FPV models, require an investment in training and technical support. Without this enabling bureaucracy, drones will underperform. A final limitation (beyond environmental factors such as bad weather and terrain morphology) is the multitude of active measures taken by the adversary to mitigate or fully nullify their effects.

Countering Drones

As this report seeks to demonstrate, drones will play an increasingly important role in the warfare of the future. Military planning must account for this and explore the value and challenges involved in drone integration at every level of force design. Just as important though consistently less discussed will be the integration of counter-drone capabilities. As one interviewed drone operator made clear:

> *In terms of evolution ... there's an increased emphasis on anti-drone capabilities ... I personally think that's something that's not talked about enough ... drones are cool and everybody's talking about them on social media ... but in the future – for example, if you're going to have an infantry platoon conducting combat operations – they're going to want to have a drone, obviously, for situational awareness. But they're absolutely going to have to have anti-drone capability with them.*[142]

This counter-drone capability includes drones themselves. Armed with nets, or grenades to function as close-proximity aerial mines, drones can engage other drones in the protection of defensive positions. Technologies are being specifically developed to function in this capacity, including the Fortem's DroneHunter F700, a six-rotored drone designed

142. Interview II.

to launch anti-drone nets. The Ukrainian military has already deployed this drone on the frontlines, usually to defend critical infrastructure (e.g., power plants). Claiming an 85% catch rate, these drones are also armed with jamming systems and radar to detect and incapacitate hostile drones.[143]

Another critical counter-drone capability is electronic warfare (EW), a term encompassing all hostile actions actualised through the strategic or tactical use of the electromagnetic spectrum. This typically means jamming, frying, or tapping into communications to neutralise, disrupt, or identify and track enemy drones. Since most drone systems utilise some form of GPS reliant on electromagnetic waves, severing or infiltrating this link is extremely effective as a counter-drone measure, as it can shorten the effective range of enemy drones by many kilometres.[144] EW systems can range from truck-based jamming stations, like the Russian Krashuka-4,[145] to counter-drone rifles using electromagnetic blasts, like the Lithuanian Skywiper EDM4S.[146] These capabilities are essential to the Ukrainian and Russian war efforts, with both investing heavily in EW to protect tanks, emplacements, systems, and soldiers from drones.

EW capabilities are one key area in which Russia holds an advantage over Ukraine. With approximately one major system covering every 10 km along the front, this counter-drone technology has effectively blocked out large portions of the battlefield from drone coverage, and it is the primary factor in the high loss figures for Ukrainian drones.[147] As the war has become increasingly immobile, Russian EW operators have had time to deploy their systems more effectively.[148] The Russian EW ca-

143. Jason Sherman, "Drone-on-Drone Combat in Ukraine Marks a New Era of Aerial Warfare," *Scientific American*, April 3, 2023. https://www.scientificamerican.com/article/drone-on-drone-combat-in-ukraine-marks-a-new-era-of-aerial-warfare/.
144. Stavros Atlasmazoglu, "Russia's Electronic Warriors Are Switching to 'Much More Subtle' Operations around the Frontlines in Ukraine," *Business Insider*, October 8, 2023, https://www.businessinsider.com/russian-electronic-warfare-tactics-changing-on-frontlines-in-ukraine-2023-10?r=US&IR=T.
145. Ibid.
146. Ashish Dangwal, "Ukraine Deploys Thousands of Lithuanian C-UAS Jamming Devices to Counter Russian Drones," *Euroasian Times*, September 22, 2023, https://www.eurasiantimes.com/nc-checked-ukraine-deploys-thousands-of-lithuanian-c-uas/.
147. Watling and Reynolds, "Russian Tactics."
148. David Axe, "Troops Knocked out 90 Percent of Ukraine's Drones," *Forbes*, December 24, 2022, https://www.forbes.com/sites/davidaxe/2022/12/24/russia-electronic-warfare-troops-knocked-out-90-percent-of-ukraines-drones/?s=08&sh=1a399a8e575c.

pacity remains its most critical asset in the drone dimension of this war, as the wide proliferation of these Soviet-era weapons, often all the way down to the platoon level, makes Ukrainian drone operations a costly venture.[149] This again speaks to the indispensability of counter-drone capabilities in the modern and future battlefield.

Ukraine's EW has also been effective at intercepting Russian cell phone communications and jamming drones, comm-links and radars, but the sheer scale and considerable sophistication of Russian EW capabilities have forced them to allocate more and more resources to destroying the adversaries' EW systems whenever possible.[150] Utilising U.S.-provided EW equipment, Ukraine has managed to identify and destroy, and in one instance even capture, several of these Russian EW systems, but still remain at a disadvantage regarding the scale of EW capabilities.[151] As one Ukrainian officer noted:

> *Before we strike with a precision-guided munition, we have to provide intelligence. Is there any suppression in that area? If that area is affected by a jamming signal, we have to find the jammer and destroy it, and only then use this weapon.*[152]

Shifting away from the tactical level, a major concern for Ukraine has been countering Russian drone attacks against its civilian population and critical infrastructure. Reflecting this, a top priority in Western mil-

149. Olearchyk, "Military Briefing;" Byman, "Ukraine's Airstrikes."

150. Abdujalil Abdurasulov, "Ukraine's Invisible Battle to Jam Russian Weapons," *BBC*, August 4, 2023, https://www.bbc.com/news/world-europe-66279650.

151. Mandeep Singh, "Russian Electronic Warfare in Ukraine, 2022-2023," *India Defence Review*, July 7, 2023, http://www.indiandefencereview.com/news/russian-electronic-warfare-in-ukraine-2022-2023/. Deconfliction is another obstacle to navigate – Ukrainian units defending against Russian drones risk jamming their own drones in the process.

152. Abdurasulov, "Invisible Battle." Because of the effectiveness and extensive use of EW capabilities, major military powers such as the United States have already begun to look into improving their existing capabilities. This investment will only increase in importance as mass assault from cheap drones becomes a more common feature of armed conflict. Speaking on the matter last year, the Under Secretary of Defence for Acquisition and Sustainment at the Pentagon stated: "The production for counter-UAS [has] to go through the roof ... It's like where we were about a year ago when we said 155 [mm artillery shells] is going to have to go to 100,000 a month." Noah Robertson, "Counter-Drone Tech Need like That of 155mm Shells: Pentagon's LaPlante," *Defense News*, December 4, 2023, https://www.defensenews.com/pentagon/2023/12/04/counter-drone-tech-need-like-that-of-155mm-shells-pentagons-laplante/.

itary aid has been air defence systems, such as the Patriot. The layering and agile deployment of these systems has allowed Ukraine to significantly blunt much (though not all) of the impact of this terror bombing.[153] In one instance, a three-day assault on Kyiv saw all Russian drones downed before they were able to detonate their explosives. Ukrainian air defences generally down 80% of enemy missiles.[154]

It should not be forgotten that every defence against drones will feature trade-offs. Electronic attacks have proven potent against both individual drones and swarms, given their wide area-of-effect. These same microwaves, however, can also harm friendly drones and other aircraft. Missiles, on the other hand, are effective but expensive on a per-shot basis. Deploying a $500,000 NASAM missile to shoot down a $20-30,000 Russian drone is bad economics.[155] There is no easy or complete solution to these challenges. What these trade-offs do highlight, however, is the need for counter-drone diversity – investments in a range of different approaches – as well as a commitment to developing and acquiring cheaper air defence. One example of the latter is the Australian Slinger system, a 30mm cannon equipped with radar capable of detecting and destroying drones at a range of 800 meters – with each explosive-based shot costing only $100-1,000.[156] It is expected to prove a strong counter for Ukraine to answer the threat of massed Russian Shahed drones.[157]

153. John A. Tirpak, "Ukraine War Shows Importance of Counter-UAS, Air Defense, Distributed Ops to Air Warfare," *Air & Space Forces Magazine*, November 14, 2022. https://www.airandspaceforces.com/ukraine-war-shows-importance-of-counter-uas-air-defense-distributed-ops-to-air-warfare/.
154. Khvostova, Margaryta and Dmytro Kryvoshiev, "The Kyiv Sanctuary: Building the Ukrainian Defense against Russian Missiles," *European Council of Foreign Relations*, June 8, 2023. https://ecfr.eu/article/the-kyiv-sanctuary-building-the-ukrainian-defence-against-russian-missiles/.
155. A 2022 analysis of a single month of Russian drone attacks estimated the cost for Russia at between $11.66m and $17.9m and more than $28.14m for Ukraine to bring down the drones. Daniel Boffrey, "Financial Toll on Ukraine of Downing Drones 'Vastly Exceeds Russian Costs'," *The Guardian*, October 19, 2022, https://www.theguardian.com/world/2022/oct/19/financial-toll-ukraine-downing-drones-vastly-exceeds-russia-costs.
156. Ibid.
157. Defense Express, "Ukraine Gets Unique Slinger Anti-Drone Weapon Station from Australian EOS," September 2, 2023, https://en.defence-ua.com/weapon_and_tech/ukraine_gets_unique_slinger_anti_drone_weapon_station_from_australian_eos-7818.html.

Table 1. Anti-drone technologies

Ukraine	Russia
CORTEX Typhon – Kinetic air defense system	Donbas 'Kubilins' – Improvised anti-drone jamming gun
KVS G-6 – Long-range, anti-drone jamming gun	Pole-21 EW System – Electronic air jamming system
Skywiper ED4MS – Long-range, anti-drone jamming gun	Repellent-Patrol EW System – Electronic air jamming system
MIM-104 Patriot – Kinetic air defense system	Igla-S MANPADS – Kinetic air defense system
Skywiper Omni – Long-range, anti-drone jamming gun	Gibka-S MANPADS – Kinetic air defense system
Flugabwehrkanonen Gepard – Kinetic air defense system	Marker ground robotic testing platform – Drone/grenade-based air defense system
Argus Interception System – Drone-based net interception system	Krashuka C4 – Electronic air jamming system
Fortem DroneHunter F700 – Drone-based jamming interception system	Murmansk-BN – Information gathering and communications jamming
Cerberus XL – Counter-drone surveillance platform	RB-341V Leer-3 – Information gathering and communications jamming
Undisclosed 30mm gun trucks – Kinetic air defense system	Krashuka-2.0 – Electronic air jamming system
Anti-UAV Defence System – Electronic air defense system	
BAE's APKWS – Laser-guided missile defense system	
Windtalker Counter-Small Unmanned Aircraft System – Long-range drone detection system	
Titan System – Identification system for choosing the optimal countertechnology	
Slinger System – Kinetic air defense system	
NASAMS – Missile air defense system	
VAMPIRE – Missile air defense system	
Viktor – Kinetic air defense system	

As this section clarifies, the battlefield advancement of drones has not gone uncontested. Rather, there is an ongoing race between drone and counter-drone capabilities, a dynamic that will endure well beyond the Russo-Ukrainian War. This dynamic will produce and accelerate many

adaptations in warfare, including the incorporation of higher levels of military AI and machine learning into the drone. The current and future role of autonomous drones is the subject of the final chapter.

4

Autonomous Drones and Ukraine

As the previous chapter outlined, Ukraine and Russia have both placed high value on drones for multiple reasons, including their ability to accelerate the tempo of operations and to offer a potent form of cheap mass. Both trends, along with the ongoing effort to offset counter-drone capabilities, are incentivising a push towards greater levels of autonomy within the drone itself. This effort to develop military AI broadly, and autonomous drones specifically, will have significant implications for Denmark's own approach to military planning and regulation going forward.

4.1. Defining Autonomous Weapons

Military AI is a broad – arguably overbroad – term encompassing a multitude of intended battlefield effects, including C4ISR, cyber operations, information warfare, and combat operations. As the previous chapter highlighted, AI has already been used to assist Ukrainian forces in data collection and analysis. The 'Delta Battle Management System', for example, has helped Ukraine to command and control forces better and to track the disposition of the Russian military in real time.[158]

158. Cronin, "Strategic Resilience."

AI is also being developed, more controversially, to complement or substitute human operators in the use of lethal force against human and material targets. The U.S. Department of Defense defines lethal autonomous weapons systems (LAWS) as systems that, 'once activated, can select and engage targets without further intervention by a human operator'.[159]

Textbox 2: Defining autonomous weapons

Throughout the international debate over the legal status of autonomous weapons, much of the disagreement has centred on: 1) how to accurately define autonomous weapons; and 2) the extent to which disagreement over this definition complicates the creation of new rules to govern the development and use of this technology. As some have argued, over-inclusive definitions of 'autonomous weapons' may lead to regulations that restrict weaponry already in (legal) use. Denmark, for example, currently possesses weapons systems with varying levels of automatic, automated, and autonomous functionality,[160] including the Harpoon Block II anti-ship missile, the Evolved Sea Sparrow surface-to-air missile, the EuroTorp MU90 Advanced Lightweight Torpedo, and the Terma Soft Kill Weapon Decoy Launching System.[161]

References are often made in these discussions to the 'kill chain' or 'decision loop'. A drone having a human 'in the loop' means that it cannot autonomously execute a target without the person's active approval. In contrast, a human 'on the loop' functions in a management role: They lack the capacity to initiate each action in the targeting cycle but can

159. U.S. Department of Defense, "DoD Directive 3000.09 Autonomy in Weapon Systems," January 25 2023, https://www.defense.gov/News/Releases/Release/Article/3278076/dod-announces-update-to-dod-directive-300009-autonomy-in-weapon-systems/. This definition excludes current fire-and-forget munitions as well as heat-seeking missiles (e.g., the Javelin and Stinger).
160. These categories refer to differences in the degree of adaption, learning, and decision making integrated into the systems.
161. Gary Schaub Jr. and Jens Wenzel Kristoffersen, "In, On, or Out of the Loop? Denmark and Autonomous Weapons Systems," *Centre for Military Studies*, February 2017, https://cms.polsci.ku.dk/publikationer/in-on-or-out-of-the-loop/In_On_or_Out_of_the_Loop.pdf.

oversee the process and intercede where needed to stop particular acts. Fully autonomous drones take the human 'out of the loop', empowering the platform to carry out each action in the decision loop autonomously, including target selection and engagement.[162]

4.2. Autonomous Weapons in Ukraine

Before detailing the current status of autonomous drones in Ukraine, the high degree of uncertainty that dominates this discussion should be acknowledged. The reasons for this uncertainty include:

- the classified status of much of this technology;
- an absence of consensus over the precise threshold between semi- and fully-autonomous drones;
- the mistaken conflation of remotely operated drones and autonomous drones in media representations and popular discourse; and
- deliberate and ongoing efforts to exaggerate the battlefield potential of autonomous drones by private actors who stand to gain financially from technology over-hype in this area.

Amidst this uncertainty, however, we can clearly observe the rising influence of AI in both the Ukrainian and Russian operations, including with respect to drones. Autonomous drones are firstly valued for their potential to mitigate the growing potency of counter-drone battlefield coverage:

> *If you look at the context of Ukraine and in a lot of ... articles you see out there about jamming, about electronic warfare, about all the different kinds of the cat-and-mouse games that Ukraine and Russia are constantly playing with each other, autonomy is one of the ways that ... a military might seek to address ... some of those challenges.*[163]

162. Human Rights Watch, "Losing Humanity: The Case against Killer Robots," November 19, 2012, https://www.hrw.org/report/2012/11/19/losing-humanity/case-against-killer-robots.
163. Michael Horowitz, cited in Patrick Turner, "The Pentagon Is Already Testing Tomorrow's AI-Powered Swarm Drones, Ships," *Defense One*, January 22, 2024, https://www.defenseone.com/technology/2024/01/pentagon-already-testing-tomorrows-ai-powered-sw

To give one example of these efforts, Ukrainian engineers are currently developing AI-targeting that allows inexpensive FPV drones to maintain their target lock even if the craft loses contact with the human operator because of environmental interference or enemy jamming.[164] These advances bring to mind a question that has dominated much of the debate over military AI in recent years: Are fully autonomous weaponised drones finally a reality? At least one recent report argues explicitly that we have now crossed this technological Rubicon. According to David Hambling of *New Scientist*:

> *Ukrainian attack drones equipped with artificial intelligence are now finding and attacking targets without human assistance ... in what would be the first confirmed use of autonomous weapons or 'killer robots'. While the drones are designed to target vehicles such as tanks, rather than infantry, it is almost certain that the resulting explosions are killing Russian soldiers without a direct command from a human operator, although no casualties have been confirmed ...*[165]

The drone in question, the Saker Scout quadcopter, can carry 3 kg of explosives and operate at a range of approximately 12 km. The drone has two autonomous modes: It can be sent into an area to autonomously reconnoitre (integrated with Ukraine's Delta intelligence distribution system), or it can autonomously find and attack targets. As the report goes on to note, however, both autonomous modes have thus far proven less reliable than having a human in the loop.

---

arm-drones-ships/393528/?oref=defenseone_today_nl&utm_source=Sailthru&utm_medium=email&utm_campaign=Defense%20One%20Today:%20January%2023%2C%2024&utm_term=newsletter_d1_today.

164. Hudson and Khudov, "War in Ukraine." AI has also been utilised to enhance battlefield targeting. According to one news outlet, the Ukrainian military has developed an AI image classifier capable of detecting camouflaged enemy vehicles, for use on armed drones. Marcin Wyrwal, "War in Ukraine: How Artificial Intelligence Is Killing Russians," *Onet*, July 13 2022, https://www.onet.pl/informacje/onetwiadomosci/rozwiazali-problem-armii-ukrainy-ich-pomysl-okazal-sie-dla-rosjan-zabojczy/pkzrk0z,79cfc278.
165. David Hambling, "Ukrainian AI Attack Drones May Be Killing without Human Oversight," *New Scientist*, October 13, 2023, https://www.newscientist.com/article/2397389-ukrainian-ai-attack-drones-may-be-killing-without-human-oversight/.

The Russian use of loitering munitions, particularly the 'AI-based autonomous' KUB-BLA, has also raised concerns that the threshold from semi- to full-autonomy has been crossed, although it remains unclear whether the technology is as advanced as advertised.[166] As experts have also pointed out, these autonomous systems are still challenged by the need to acquire necessary training data, and it is unlikely that Russia has overcome this limitation.[167]

What is less contestable, however, is the clear interest among the Ukrainian and Russian militaries to embrace autonomous weapons. Fully autonomous armed drones are 'a logical and inevitable next step', argues Ukraine's digital transformation minister, Mykhailo Fedorov.[168] The Chief Executive of AeroVironent, the creator of the Switchblade drone, echoes this: 'the technology to achieve a fully autonomous mission ... pretty much exists today'.[169] Russia similarly views this technology as indispensable to future war and is looking to substitute human combatants for drones, robots, and algorithms where possible. We can expect a further embrace of this technology by Russia once the not insignificant technological hurdles are cleared.[170]

As noted above, this drive to develop and improve autonomous drones is partly a by-product of the drone/counter-drone dynamic characterising the Russo-Ukrainian War. Two other important drivers of autonomous drones are speed and mass. In discussions over whether and how to regulate autonomous violence, major powers, including the U.S., the UK, and Russia, have made clear their unwillingness to prematurely abandon a technology that can potentially convey a significant battlefield advantage. Part of this advantage relates to the expectation of speed; future warfare will operate at faster speeds, and states think that they must match this intensity or fall behind. Lethal autonomous weapons, it is argued, 'have the unique potential to operate at a tempo faster

166. Gregory C. Allen, "Russia Probably Has Not Used AI-Enabled Weapons in Ukraine, but That Could Change," *Centre for Strategic and International Studies*, May 26, 2022, https://www.csis.org/analysis/russia-probably-has-not-used-ai-enabled-weapons-ukraine-could-change.
167. Ibid.
168. Cited in Frank Bajak and Hanna Arhirova, "Drone Advances in Ukraine Could Bring Dawn of Killer Robots," *Los Angeles Times*, January 3, 2023, https://www.latimes.com/world-nation/story/2023-01-03/drone-advances-in-ukraine-dawn-of-killer-robots.
169. Ibid.
170. Marcinek and Han, "Russia's Asymmetric Response."

than humans can possibly achieve'.[171] Though humans remain integral to most critical military functions in the Russo-Ukrainian War, the pursuit of ever-greater levels of combat speed will likely incentivise further investments in autonomous drones, especially as the systems improve.

Cheap mass is another major driver of autonomous drones. As the previous chapter highlighted, inexpensive drones are currently favoured in Ukraine for their potential to overwhelm enemy defences at a relatively low cost. Inexpensive FPV drones increasingly complement (not replace) traditional platforms, delivering massed firepower to the battlefield.[172] The growing autonomy of these weapons may extend these benefits. Ukraine is looking to develop and deploy inexpensive swarms of 'autonomous FPV drones that do not require a skilled operator [and] are immune to radio jamming'.[173] These AI drone swarms will, it is hoped, provide a cost-effective means for warring parties to loosely distribute and then concentrate forces rapidly in the battlefield locations where they most enjoy tactical advantage.[174] According to former Google CEO Eric Schmidt, who has advised the Pentagon on AI matters, drone technology will play a decisive role in all domains of future war, including the use of 'ruthless swarms of AI-empowered kamikaze drones'.[175]

These optimistic claims should be treated with significant caution. Schmidt and other private actors have a vested financial interest in promoting a model of future warfare in which drones and autonomous weapons play an indispensable role. Scepticism is also needed concerning military AI more broadly, and the techno-optimistic assumptions

171. Jeffrey S. Thurnher, "Legal Implications of Fully Autonomous Targeting," *Joint Force Quarterly* 67 (4th Quarter, October 2012): 83, March 8, 2017, http://ndupress.ndu.edu/Portals/68/Documents/jfq/jfq-67/JFQ-67_77-84_Thurnher.pdf. The potential moral downside of such an increase is detailed in the next section.
172. David Hambling, "Could Small Drones Really Replace Artillery?," *Forbes*, August 16, 2023, https://www.forbes.com/sites/davidhambling/2023/08/16/could-small-drones-really-replace-artillery/?sh=3fcfee431a83; The Economist, "Killer Drones Pioneered in Ukraine Are the Weapons of the Future," *The Economist*, February 8, 2024, https://www.economist.com/leaders/2024/02/08/killer-drones-pioneered-in-ukraine-are-the-weapons-of-the-future.
173. The Economist, "How Could FPV Drones Change Warfare?," *The Economist*, August 4 2023, https://www.economist.com/the-economist-explains/2023/08/04/how-could-fpv-drones-change-warfare?utm_medium=social-media.content.np&utm_source=twitter&utm_campaign=editorial-social&utm_content=discovery.content.
174. Kenneth Payne, "I-Warbot: The Dawn of Artificially Intelligent Conflict", *Oxford University Press*, 2021, pp. 106-107.
175. Cited in Hudson and Khudov, "War in Ukraine."

underpinning much of the excitement over its current and future promise. Too often, these accounts exaggerate the potential of AI to render the battlefield knowable and controllable,[176] offering a flawed vision of future warfare:

> *... in which advanced technology makes the processes of military decision-making akin to bouncing a few requests for intelligence or courses of action off an AI-enabled chat system. It envisions complete knowledge of the enemy, the capacity for friendly forces to act unburdened by opposition, and the ability to rapidly generate a list of reliable plans of attack in only seconds.*[177]

It is highly unlikely that military AI and autonomous weapons will meet the expectations of their strongest proponents. The perception that they may fully or partially do so, however, is a powerful driver of investment. The U.S. Air Force is planning to build between 1,000-2,000 AI drones with the capability to perform a range of tasks that include swarm attacks. This technology, significantly cheaper than manned aircraft alternatives, will function, it is hoped, as a form of 'affordable mass'.[178] According to Deputy Defence Secretary Kathleen Hicks, these drones will help the United States to 'overcome the PRC's biggest advantage, which is mass ... More ships. More missiles. More people'.[179]

176. For more information on the military limitations of AI, see Cameron Hunter and Bleddyn Bowen, "We'll Never Have a Model of an AI Major-General: Artificial Intelligence, Command Decisions, and Kitsch Visions of War," *Journal of Strategic Studies* 47, no. 1, 2024: 116-46; Avi Goldfarb and Jon R. Lindsay, "Prediction and Judgement: Why Artificial Intelligence Increases the Importance of Humans in War," *International Security* 46, no. 3. Winter 2021-2022: 7-50.
177. Ian Reynolds and Ozan Ahmet Cetin, "War Is Messy. AI Can't Handle It," *Bulletin of the Atomic Scientists*, August 14, 2023, https://thebulletin.org/2023/08/war-is-messy-ai-cant-handle-it/?utm_source=SocialShare.
178. Eric Lipton, "A.I. Brings the Robot Wingman to Aerial Combat," *The New York Times*, August 27, 2023, https://www.nytimes.com/2023/08/27/us/politics/ai-air-force.html.
179. Cited in William D. Hartung, "Beware of Pentagon Techno-Enthusiasm," *Defense One*, August 31, 2023, https://www.defenseone.com/ideas/2023/08/beware-pentagon-techno-enthusiasm/389885/. These efforts are not limited to 'great' powers. A Turkish defence company, for example, recently tested a scenario in which two 'Baha sub-cloud' uncrewed vehicles, two unmanned ground vehicles, and a five-drone swarm performed together to surveil the battlefield and provide reconnaissance, and direct ground vehicles to identify targets. Tayfun Ozberk, "Turkey's Havelsan Tests Robots, Drone Swarms for Digital Troop Concept,"

Danish drone companies are also looking to develop more autonomous software, although the extent of these projects remains relatively unknown.[180] Even for states such as Denmark with small drone sectors, the potential military and financial gains from autonomous innovation is driving investment to a degree that will shape the next generation of drone weaponry.

As this section has outlined, autonomous drones are rapidly becoming a battlefield reality, driven by the military exigencies of Russia and Ukraine. Importantly, though, the appeal of these weapons goes beyond this specific war; numerous state actors are seeking to develop and deploy a range of military AI capabilities, including autonomous drones. This perception (often mistakenly inflated) of indispensability and inevitability highlights the difficulty – but also the critical importance – of effective governance over this emerging technology.

4.3. Regulating Autonomous Drones

Autonomous drone technology is advancing at a pace vastly exceeding the accompanying regulatory efforts. This is problematic given the technical, moral, legal, and strategic-stability challenges that such weapons pose.

As already noted, some military experts and practitioners argue that the technological potential of autonomous weapons to deliver unprecedented clarity and precision to the battlefield is overblown. Autonomous weapons will need to be trained, not merely programmed; data dependence may lead to 'brittle' systems that only work reliably in battlefield environments that directly match the training data.[181] Alternatively, these systems may be under-trained, increasing the risk of autonomous drones acting in unanticipated or undesirable ways. A logic of

Defense News, August 24, 2023, https://www.defensenews.com/unmanned/2023/08/24/turkeys-havelsan-tests-robots-drone-swarm-for-digital-troop-concept/.

180. Interview III.

181. Ingvild Bode and Tom Watts, "Loitering Munitions and Unpredictability: Autonomy in Weapon Systems and Challenges to Human Control," *AutoNorms*, June 7, 2023, https://www.autonorms.eu/loitering-munitions-and-unpredictability-autonomy-in-weapon-systems-and-challenges-to-human-control/.

iteration through error and unsupervised calculation is a key element in autonomous weapons training.[182] In practical terms, this means that system updates and improvements may be paid for in unintended but foreseeable harm to civilians.

Concerns have also been raised over the speed-centric vision of war driving much of the optimism around autonomous weapons. As U.S. Department of Defense officials have argued, 'future conflicts may require decisions to be made within hours, minutes, or potentially seconds compared with the multiday process to analyse the operating environment and issue commands'.[183] The USMC Force Design 2030 update echoes this: 'Marines must fight at machine speed or face defeat at machine speed'.[184] Autonomous drones are a key aspect of this vision, given their potential to compress the kill chain by removing the 'redundancy' of direct human control.

Too often missing from this planning, however, is adequate reflection on the degree to which this pursuit of battlefield speed might complicate our ability to effectively discharge our moral and legal duties on the battlefield, particularly in relation to civilian protection.[185] Compounding this challenge is the potential for this technology to dilute battlefield responsibility and complicate the allocation of accountability in the event of moral or legal infractions.

Beyond the moral and legal challenges associated with autonomous weapons, critics also highlight the potential of this technology to further destabilise strategic stability. For the United States, China, and Russia in particular, a key driver of innovation in this area is the perceived need to modernise warfare to confront the military threat of geopolitical rivals. An unintended by-product of this pursuit may be a level of 'strategic

182. Neil Renic and Elke Schwarz. "Crimes of Dispassion: Autonomous Weapons and the Moral Challenge of Systematic Killing," *Ethics & International Affairs*, 37, no. 3 (2023): 321-43.

183. Congressional Research Service, "Joint All-Domain Command and Control: Background and Issues for Congress," Congressional Research Service, January 21 2022, https://sgp.fas.org/crs/natsec/R46725.pdf.

184. United States Marine Corps, "Force Design 2030: Annual Update," June 2023, https://www.marines.mil/Portals/1/Docs/Force_Design_2030_Annual_Update_June_2023.pdf.

185. It should be noted that many contest this framing of autonomous weapons as morally and legally faulty. For a good overview of the 'humanitarian' case for autonomous weapons, see Kevin Jon Heller, 2023, "The Concept of 'The Human' in the Critique of Autonomous Weapons," *Harvard Law School National Security Journal*, https://harvardnsj.org/2023/12/15/the-concept-of-the-human-in-the-critique-of-autonomous-weapons/.

competition and distrust'[186] that brings states closer to the very war these technologies are designed (at least partly) to deter against. An AI 'arms race' would also increase the likelihood of states prematurely fielding weapons that expose civilians to unacceptably high levels of harm.

International efforts to mitigate these risks have been ongoing within the United Nations Convention on Certain Conventional Weapons (CCW). The CCW entered into force in 1983 and was established to restrict or prohibit particular weapons deemed excessively injurious or indiscriminate in their effects. The CCW took up the issue of autonomous weapons in 2014, and a Group of Governmental Experts (GGE) was formed in 2016. Since its creation, the GGE debate between state and non-state actors has been primarily split between those seeking a legal ban on the development and use of autonomous weapons and those opposing such a ban.

Denmark has participated in the CCW debate since 2015, where it argued that 'all use of force – including the use of autonomous weapon systems – must be in compliance with international humanitarian law (i.e., the fundamental rules of distinction, proportionality, and precaution in attack). And all use of force must remain under "meaningful human control".[187] In March 2023, Denmark indicated support for a 'two-tier approach' to the regulation of this technology, releasing a joint statement with Bulgaria, Finland, France, Germany, Italy, Luxembourg, the Netherlands, Norway, Spain, and Sweden:

> *High Contracting parties should acknowledge that firstly, lethal autonomous weapons systems that cannot comply with IHL are ipso facto prohibited and should be outlawed and not be developed or used, while regulating any other lethal weapons systems featuring autonomy in order to ensure compliance with the rules and principles of international humanitarian law, by preserving human responsibility and account-*

186. James Johnson, "Artificial Intelligence and Future Warfare: Implications for International Security," *Defence and Security Analysis*, 35, no. 2 (2019): 147-69.

187. Statement by Denmark, CCW Informal Meeting of Experts on LAWS, 13 April 2015, https://www.reachingcriticalwill.org/images/documents/Disarmament-fora/ccw/2015/meeting-experts-laws/statements/13April_Denmark.pdf.

ability, ensuring appropriate human control, and implementing risk mitigation measures.[188]

In December that same year, Denmark joined 151 other countries to vote in favour of General Assembly Resolution 78/241, recognising the 'serious challenges and concerns' raised by 'new technological applications in the military domain, including those related to artificial intelligence and autonomy in weapons systems'.[189]

Given the powerful and growing state interest in this technology, we are unlikely to see a draft treaty emerge from the CCW process that will satisfy critics of autonomous drones. What is clear, however, is that more must be done to clarify and address the challenges posed by this technology. If fully autonomous drones are not yet a reality in war, they soon will be, at least in some capacity. In the context of the Russo-Ukrainian War, the drive to nullify counter-drone jamming has incentivised experimentation with autonomy. The lure of greater speed and mass in war will further drive states to incorporate AI into their weapons systems. More ambition is needed from states, including Denmark, to address the foreseeable risks and dangers generated by this shift to increasingly autonomous violence.

188. "Meeting of the CCW Group of Governmental Experts on 'Emerging Technologies in the Area of Lethal Autonomous Weapons Systems' (LAWS)," *UNODA*, March 6-10, 2023, https://meetings.unoda.org/meeting/67246/statements.

189. "UN General Assembly Adopts Resolution on Lethal Autonomous Weapons Systems," *digwatch*, December 25, 2023, https://dig.watch/updates/un-general-assembly-addopted-resolution-on-lethal-autonomous-weapons-systems-or-laws.

5

Conclusions and Recommendations

Having reviewed the proliferation trends, battlefield use, and growing autonomy of drones in the context of the Russo-Ukrainian War, the report now summarises our overall conclusions and recommendations. The Russo-Ukrainian War is a massive, existential, inter-state conflict, featuring large-scale societal mobilisation on both sides. The conflict is also distinct in the level and effect of international military aid. This distinctiveness matters, as not every lesson drawn from this conflict will be fully applicable to Denmark. This report has primarily focused on the evolving trends and patterns in the character and trajectory of drone warfare. An understanding of both will help Danish decision makers better navigate future challenges relating to the investment, training, regulation, and use of drones.

5.1. Conclusions

The report first detailed the *proliferation* of drones. States are working to acquire, develop, and distribute drone and counter-drone capabilities across the globe, especially in conflict-prone areas. The international drone landscape is becoming denser and more diversified, as military-grade and commercial drones, as well as increasingly autonomous systems, reach actors in Europe, the Middle East, Central and South Asia, and West and East Africa. States are working both to diversify

their drone arsenals and to increase the scale of drone production. While the Russo-Ukrainian War has highlighted the growing importance of expendable, commercial drones, military-grade drones will retain a role in strategic missions. Going forward, we can expect states to prioritise mixed aerial arsenals: sophisticated drone platforms for strategic ISR and deeper strikes, and smaller, inexpensive drones for tactical use.[190] Procurement strategies will reflect these evolving priorities.

States are also working to innovate drones. The growing role of the private and public sectors in drone development will accelerate this innovation, and we should expect drone technology to improve 'not at the budget-cycle pace of the military-industrial complex, but with the break-things urgency of consumer electronics'.[191] The speed and intensity of these changes speaks to the importance of future planning. States will look to create and maintain stable lines of access to drone technology.

The report next evaluated the *battlefield use* of drones. The Russo-Ukrainian War re-confirms that drones are not a 'silver bullet'. They cannot overturn inadequacies in force design, employment, and quality, nor the disadvantages stemming from poor logistics. Drones retain limitations that can only be mitigated, not overcome. As the conflict further reveals, however, drone technology has unequivocally moved from a peripheral to a central feature of war. Drones enhance ISR capabilities; give greater battlefield autonomy to those equipped; improve both the volume and precision of strikes; and increase the pace and lethality of attacks. Critically, however, these benefits are not automatic. States that prioritise flexibility and adaptability will gain more value from this technology than states that do not. An inclination to experiment and innovate (responsibly) will be needed, as well as a willingness to permit and encourage independent decision-making at all levels of the command structure.

The evolving role of drones will also shape the defensive calculations of states. Battlefields of the future will be saturated with sensors, increasing the difficulty of avoiding detection from the adversary. The intensity of this coverage will heavily affect the ability of belligerents to conduct

190. Kerry Chávez and Ori Swed, "Emulating Underdogs: Tactical Drones in the Russia-Ukraine War," *Contemporary Security Policy*, 44, no. 4 (2023), 592-605, p. 601.
191. *The Economist*, "Killer Drones."

fast offensives, concentrate and distribute forces, and establish zones of autonomous defence.[192] This lesson is already reaching modern militaries, with both the United States[193] and United Kingdom[194] underlining the need for observational capacities, dispersion, speed, autonomy, and sustainable logistics. Increasing battlefield transparency will also drive significant investments in advanced counter-drone technologies. Just as with drones themselves, this counter-drone capacity will need to prioritise both mass and cost-effectiveness. Technologies will be needed that not only defend against drones effectively but do so in an affordable manner.

The report concluded with an evaluation of the role of *autonomous drones* in the Russo-Ukrainian War. The drive to develop and improve this technology is partly a consequence of the drone/counter-drone dynamic that characterises the conflict. Autonomous weapons, it is hoped, will allow those empowered to better offset counter-drone jamming. Enthusiasm for this technology is also grounded in the belief that they will speed up combat operations by compressing the kill chain and giving warring parties access to cheap and lethal mass in the form of autonomous swarms.

The emergence of fully autonomous armed drones is consequential enough in itself but should also be understood as a single element in a broader shift towards increasingly networked, domain-crossing warfare that connects data sensors and weapons systems to an unprecedented degree to enhance the speed and scale of operations. As with drones, however, military AI and autonomous weapons will be no 'silver bullet'. This space is currently awash with exaggerated claims regarding the battlefield potential of these technologies. States that resist this techno-overhype will be better positioned to navigate the future of war responsibly. Just as important will be a commitment to strict moral and legal safeguards regarding the development and use of military AI. Innovation in the ab-

192. Office of the Director of National Intelligence, "Deeper Looks: The Future of the Battlefield," March 2021, https://www.dni.gov/index.php/gt2040-home/gt2040-deeper-looks/future-of-the-battlefield.
193. James Rainy and Laura Potter, "Delivering the Army of 2023," *War on the Rocks*, August 6, 2023, https://warontherocks.com/2023/08/delivering-the-army-of-2030/.
194. The British Army, "Army Announces New Way of Winning Future Wars," September 16, 2023, https://www.army.mod.uk/news-and-events/news/2023/09/army-announces-new-way-of-winning-future-wars/.

sence of such standards will create a problematically wide scope of possibility for misuse.

What can Denmark do to ensure that its armed forces are made stronger, not more vulnerable, by these significant changes in the drone landscape? The following recommendations build upon four major themes: 1) sustainable affordability in the development and acquisition of drone and counter-drone capabilities; 2) strengthened international cooperation on a drone industrial strategy; 3) coherent policy for addressing the significant moral and legal challenges of autonomous weapons and military AI; and 4) urgency in undertaking all necessary action.

5.2. Recommendations

1. **Update the European and Danish mind-set on drones.** For decades, the European debate on drones has been shaped by the remote warfare conducted during the Global War on Terror in the 2000s and 2010s. The Danish debate has also placed heavy emphasis on Arctic surveillance. The primary focus in both has been high-end, military-grade drones. The debate must now be updated. The contemporary drone landscape has undergone radical transformation, especially in relation to the surge of inexpensive, commercially available, disposable, and highly versatile drones, which are acquired and expended at scale. Militaries will operate on a battlefield saturated with drone and counter-drone technology, and they must plan for that future accordingly. The changing status of battlefield drones necessitates an equally significant change in doctrinal planning.
2. **Decide whether and how to acquire armed drones.** If the Danish government opts to acquire armed drones, the technology will need to be integrated into all levels of force design going forward. The ISR capability of drones alone will make this a necessity. At the same time, however, Danish policymakers must not lose sight of the fact that drones, for all their value, are an *additive* in war; they will complement and enhance existing systems but rarely replace them entirely.
3. **Invest in counter-drone systems.** If the Danish armed forces are to operate on future battlefields effectively, significant investments are needed in counter-drone technology, including electronic war-

fare and air defence systems. As with drones, this capability will require time, resources, and training, and Denmark must work to find the right balance and accept the inevitable trade-offs between effectiveness, mass, scale, and cost. The best counter-drone system for Denmark will not necessarily be the strongest-performing counter-drone system on the market – the procurement and development of these technologies requires a long-term cost-benefit analysis. It also requires the ambition and resources to act now. Delays in the procurement of counter-drone systems will leave Danish combatants dangerously exposed on the battlefield.

4. **Undertake a health audit of the current relationship between domestic drone suppliers and the Danish armed forces.** Going forward, the logistical pressures to maintain drone stockpiles will be more akin to bullet and artillery shell acquisition than tanks and aircraft. To meet domestic needs and succeed in the multi-billion-dollar drone procurement market, Denmark will need flexible and responsive bureaucracies, innovative drive, the space and culture to experiment at strategic and tactical levels, and strong government-industry ties. Ukraine is developing and modifying drones at a rapid pace in a low-regulation environment due to the existential threat it faces from Russia. Denmark must consider both the advantages and risks afforded by this easing of regulatory burdens. Its own approach should not mirror Ukraine, but rather its own internal review of future military exigencies and responsibilities.
5. **Assess the current level of vulnerability of critical infrastructure to drone attack.** Denmark should prepare for a future in which terrorists and other hostile actors have ever-greater access to cheap and effective means of societal disruption. This again speaks to the importance of cost-effective counter-drone investment. The more advanced a given defensive system is, the more costly it is likely to be to develop, resupply, and maintain.[195] As with military defence, critical infrastructure defence will need to prioritise *sustainable affordability*.
6. **Develop a comprehensive policy on the development and use of autonomous weapons.** Denmark must follow the lead of its allies, such as the United Kingdom and the United States, and formulate

195. Barret, "Industrial Base."

a national policy on autonomous weapons systems. This should include a clear articulation of the Danish position on the precise threshold between legally unproblematic and problematic autonomy in drones. Denmark must also, however, recognise the limits of debating the status of autonomous weapons through an exclusively legal lens. A comprehensive ethical framework is needed, one that seriously considers the direct and indirect moral challenges of the technology, especially in relation to civilian protection. Denmark has an opportunity and responsibility to lead, not as a military first-mover, but rather as a voice of prudence, identifying overlooked risks and uncertainties, and better articulating not only the reach but also the limitations of autonomous warfare.

7. **Help to foster military cooperation on drone and counter-drone operations in Europe.** One key takeaway from the Russo-Ukrainian War has been the need for a robust and capable defence industrial base in Europe. Thus far, this has centred primarily on the mass production of artillery shells and other munitions. This effort is important, but it must expand to include a comprehensive European drone and counter-drone strategy. Smaller European militaries, including Denmark, would benefit from better pooling knowledge on the experience and challenges of drone procurement, integration, and operations, allowing for easier and faster development in this vital security area. Collaboration on design and investment in mass-produced, small drone models and affordable counter-drone systems should be pursued at the NATO, EU, and inter-state levels. Opportunities for Nordic cooperation should also be explored where feasible.

Bibliography

Abdurasulov, Abdujalil. "Ukraine's Invisible Battle to Jam Russian Weapons." *BBC*, August 4, 2023. https://www.bbc.com/news/world-europe-66279650.

Al Jazeera. "Russian Drone Raid Kills 1 in Ukraine's Odesa, Kyiv Repels Missile Attack." *Al Jazeera*, September 6, 2023. https://www.aljazeera.com/news/2023/9/6/russian-drone-raid-kills-1-in-ukraines-odesa-kyiv-repels-missile-attack.

Allen, Gregory C. "Russia Probably Has Not Used AI-Enabled Weapons in Ukraine, but That Could Change." *Centre for Strategic and International Studies*, May 26, 2022. https://www.csis.org/analysis/russia-probably-has-not-used-ai-enabled-weapons-ukraine-could-change.

Antoniuk, Daryna. "How Electronic Warfare Is Reshaping the War between Russia and Ukraine." *The Record*, August 16, 2023. https://therecord.media/how-electronic-warfare-is-reshaping-the-war-between-russia-and-ukraine.

Associated Press. "How Russia Is Using Iranian Killer Drones to Spread Terror in Ukraine." *PBS NewsHour*, October 17, 2022. https://www.pbs.org/newshour/world/how-russia-is-using-iranian-killer-drones-to-spread-terror-in-ukraine.

Atlamazoglou, Stavros. "Russia's Electronic Warriors Are Switching to 'Much More Subtle' Operations around the Frontlines in Ukraine." *Business Insider*, October 8, 2023. https://www.businessinsider.com/russian-electronic-warfare-tactics-changing-on-frontlines-in-ukraine-2023-10.

Atlantic Council. "Airpower after Ukraine: The Future of Air Warfare." *Atlantic Council*, August 2, 2023. https://www.atlanticcouncil.org/programs/scowcroft-center-for-strategy-and-security/forward-defense/airpower-after-ukraine/.

Axe, David. "Russia's Electronic-Warfare Troops Knocked out 90 Percent of Ukraine's Drones." *Forbes*, December 24, 2022. https://www.forbes.com/sites/davidaxe/2022/12/24/russia-electronic-warfare-troops-knocked-out-90-percent-of-ukraines-drones/.

Axe, David. "The Russians Reportedly Knocked out Two More Ukrainian Leopard 2 Tanks. That's Five Leopard 2 Losses in a Week." *Forbes*, October 28, 2023, sec. *Aerospace & Defense*. https://www.forbes.com/sites/davidaxe/2023/10/28/the-russians-reportedly-knocked-out-two-more-ukrainian-leopard-2-tanks-thats-five-leopard-2-losses-in-a-week/.

Bajak, Frank, and Hanna Arhirova. "Drone Advances in Ukraine Could Bring Dawn of Killer Robots." *Los Angeles Times*, January 3, 2023. https://www.latimes.com/world-nation/story/2023-01-03/drone-advances-in-ukraine-dawn-of-killer-robots.

Barrett, John. "You Go to War With the Industrial Base You Have, Not the Industrial Base You Want." *War on the Rocks*, August 16, 2023. https://warontherocks.com/2023/08/you-go-to-war-with-the-industrial-base-you-have-not-the-industrial-base-you-want/.

Bath, Alison. "Ukrainian Drone Attack Could Be Precursor to New Maritime Fight in War with Russia." *Stars and Stripes*, November 7, 2022. https://us2.campaign-archive.com/?e=7a3da21f61&u=f141047f5265cca1bca1a0c28&id=15c90ac709.

Bendett, Samuel. "Roles and Implications of AI in the Russian-Ukrainian Conflict." *Russia Matters*, July 20, 2023. https://www.russiamatters.org/analysis/roles-and-implications-ai-russian-ukrainian-conflict.

Bennett, Dalton, and Mary Ilyushina. "Inside the Russian Effort to Build 6,000 Attack Drones with Iran's Help." *The Washington Post*, August 17, 2023. https://www.washingtonpost.com/investigations/2023/08/17/russia-iran-drone-shahed-alabuga/.

Bendett, Samuel [@sambendett]. "1/ Since the Start of Russia's Invasion of Ukraine, Russian Forces Lacked Enough Tactical Drones That Were (and Still Are) Eventually Procured by Volunteers. It Appeared That the Russian MOD Has No Way to Send Enough Quadcopters to the Front. However..." Tweet. *Twitter*, April 6, 2023. https://twitter.com/sambendett/status/1643990213067411464.

Bendett, Samuel [@sambendett]. "The First 5,000+ FPV Drones from Operation Unity Are Already in Ukraine. Next, the Drones Will Be Supplemented with Ukrainian-Made Munitions. There Will Be 10,000 FPV Drones in Total. These Drones Were Purchased Thanks to the Joint Collection of UNITED24, Povarnys Alive And... https://T.Co/JLrZOz29Xo." Tweet. *Twitter*, October 11, 2023. https://twitter.com/sambendett/status/1712087538410660219.

Bergen, Peter, Melissa Salyk-Virk, and David Sterman. "World of Drones." *New America*, July 30, 2022. https://www.newamerica.org/future-security/reports/world-drones/who-has-what-countries-with-armed-drones/.

Bergengruen, Vera. "How Tech Giants Turned Ukraine into an AI War Lab." *TIME*, February 8, 2024. https://time.com/6691662/ai-ukraine-war-palantir/.

Biddle, Stephen. "Ukraine and the Future of Offensive Maneuver." *War on the Rocks*, November 22, 2022. https://warontherocks.com/2022/11/ukraine-and-the-future-of-offensive-maneuver/.

Bisht, Inder Singh. "Russian Drone Plant Built with Iranian Help Opens." *The Defense Post*, July 10, 2023. https://www.thedefensepost.com/2023/07/10/russian-drone-plant-iranian/.

Bode, Ingvild, and Tom Watts. "Loitering Munitions and Unpredictability: Autonomy in Weapon Systems and Challenges to Human Control - AutoNorms." *Center for War Studies*, June 7, 2023. https://www.autonorms.eu/loitering-munitions-and-unpredictability-autonomy-in-weapon-systems-and-challenges-to-human-control/.

Boffey, Daniel. "Financial Toll on Ukraine of Downing Drones 'Vastly Exceeds Russian Costs.'" *The Guardian*, October 19, 2022, sec. World news. https://www.theguardian.com/world/2022/oct/19/financial-toll-ukraine-downing-drones-vastly-exceeds-russia-costs.

Borodikin, Alexander. "'A Defeat for Russia Is Not a Victory for Ukraine.' An Interview with Military Analyst Michael Kofman." *Mediazona*, May 12, 2023. https://en.zona.media/article/2023/05/12/KofmanMichael.

Borsari, Federico. "Assessing Drone Operations in Ukraine: Trends and Implications." Orion Policy Institute, July 19, 2022. https://www.orionpolicy.org/orionforum/110/assessing-drone-operations-in-ukraine-trends-and-implications.

Borsari, Federico. "Turkey's Drone Diplomacy: Lessons for Europe." ECFR, January 31, 2022. https://ecfr.eu/article/turkeys-drone-diplomacy-lessons-for-europe/.

Bundesregierung, "Military Support for Ukraine." Bundesregierung, November 1, 2023, https://www.bundesregierung.de/breg-en/news/military-support-ukraine-2054992.

Bundesregierung. "The Arms and Military Equipment Germany Is Sending to Ukraine." Bundesregierung, February 26, 2024. https://www.bundesregierung.de/breg-en/news/military-support-ukraine-2054992.

Byman, Daniel. "Are Ukraine's Airstrikes in Russia Effective?" *Foreign Policy* (blog), March 28, 2024. https://foreignpolicy.com/2023/10/04/ukraines-airstrikes-inside-russia-moscow-drones-war-strategy/.

Byrne, James, Jack Watling, Justin Bronk, Gary Somerville, Joe Byrne, Jack Crawford, and Jane Baker. "The Orlan Complex: Tracking the Supply Chains of Russia's Most Successful UAV." RUSI, December 15, 2022. https://rusi.orghttps://rusi.org.

Calcara, Antonio, Andrea Gilli, Mauro Gilli, and Ivan Zaccagnini. "Air Defense and the Limits of Drone Technology." Default, July 31, 2022. https://www.lawfaremedia.org/article/air-defense-and-limits-drone-technology.

Carus, W. Seth. "The Bekaa Valley Campaign." *The Washington Quarterly* 5, no. 4 (1982): 34–41.

Chávez, Kerry, and Ori Swed. "Emulating Underdogs: Tactical Drones in the Russia-Ukraine War." *Contemporary Security Policy* 44, no. 4 (September 21, 2023): 592–605. https://doi.org/10.1080/13523260.2023.2257964.

Chávez, Kerry, and Ori Swed. "How Hamas Innovated with Drones to Operate like an Army." *Bulletin of the Atomic Scientists* (blog), November 1, 2023. https://thebulletin.org/2023/11/how-hamas-innovated-with-drones-to-operate-like-an-army/.

Cole, Chris. "Armed Drone Proliferation Update – March '23." Drone Wars UK, March 22, 2023. https://dronewars.net/2023/03/22/armed-drone-proliferation-update-march-23/.

Cole, Chris. "Proliferation of Armed Drones Continues Apace Resulting in Numerous Civilian Casualties." *Drone Wars UK*, February 13, 2024. https://dronewars.net/2024/02/13/proliferation-of-armed-drones-continues-apace-resulting-in-numerous-civilian-casualties/.

Cole, Chris. "Rise of the Reapers: A Brief History of Drones." *Drone Wars UK*, October 6, 2014. https://dronewars.net/2014/10/06/rise-of-the-reapers-a-brief-history-of-drones/.

Conflict Armament Research. "Documenting the Domestic Russian Variant of the Shahed UAV." Conflict Armament Research, January 19, 2024. https://storymaps.arcgis.com/stories/d3be20c31acd4112b0aecece5b2a283c.

Congressional Research Service. "Joint All-Domain Command and Control: Background and Issues for Congress." Congressional Research Service, January 21, 2022. https://sgp.fas.org/crs/natsec/R46725.pdf.

Cook, Ellie. "From Abrams to Leopards: The Cost of Western Tanks Being Sent to Ukraine." *Newsweek*, January 26, 2023. https://www.newsweek.com/cost-western-battle-tanks-m1-abrams-leopard-2-challenger-2-1776725.

Cranny-Evans, Sam. "Russia's Artillery War in Ukraine: Challenges and Innovations." RUSI, March 20, 2024. https://rusi.orghttps://rusi.org.

Cronin, Audrey Kurth. "Open Source Technology and Public-Private Innovation Are the Key to Ukraine's Strategic Resilience." *War on the Rocks*, August 25, 2023. https://warontherocks.com/2023/08/open-source-technology-and-public-private-innovation-are-the-key-to-ukraines-strategic-resilience/.

Dangwal, Ashish. "Ukraine Deploys Thousands of Lithuanian C-UAS Jamming Devices to Counter Russian Drones." *Latest Asian, Middle-East, EurAsian, Indian News* (blog), September 22, 2023. https://www.eurasiantimes.com/nc-checked-ukraine-deploys-thousands-of-lithuanian-c-uas/.

Dangwal, Ashish. "Ukraine 'Invites' US Defense Firms to Test Their Weapons in Active Conflict Zone; Says Must Resist Russian EW Attacks." *Latest Asian, Middle-East, EurAsian, Indian News*, March 6, 2023. https://www.eurasiantimes.com/ukraine-invites-us-defense-firms-to-test-their-weapon-systems/.

Defence Express. "What EW Systems and 'Drone Killers' Has Ukraine Received to Counter Lancets and Shahed-136 Combat UAVs? | Defense Express." *Defence Express*, November 24, 2023. https://en.defence-ua.com/weapon_and_tech/what_ew_systems_has_ukraine_received_to_counter_lancets_and_shahed_136_combat_uavs-8655.html.

Defense Express. "Ukraine Gets Unique Slinger Anti-Drone Weapon Station from Australian EOS | Defense Express." *Defense Express*, September 2, 2023. https://en.defence-ua.com/weapon_and_tech/ukraine_gets_unique_slinger_anti_drone_weapon_station_from_australian_eos-7818.html.

Detsch, Jack. "How Ukraine Learned to Fight." *Foreign Policy* (blog), March 28, 2024. https://foreignpolicy.com/2023/03/01/how-ukraine-learned-to-fight/.

Dickinson, Peter. "Ukraine Needs Urgent Air Defense Aid as Putin Launches Bombing Campaign." *Atlantic Council* (blog), January 2, 2024. https://www.atlanticcouncil.org/blogs/ukrainealert/ukraine-needs-urgent-air-defense-aid-as-putin-launches-bombing-campaign/.

Digital Watch Observatory. "UN General Assembly Adopts Resolution on Lethal Autonomous Weapons Systems." *Digital Watch Observatory* (blog), December 25, 2023. https://dig.watch/updates/un-general-assembly-addopted-resolution-on-lethal-autonomous-weapons-systems-or-laws.

Dilanian, Ken, Courtney Kube, and Carol E. Lee. "U.S. Intel Helped Ukraine Sink Russian Flagship Moskva, Officials Say." *NBC News*, May 5, 2022. https://www.nbcnews.com/politics/national-security/us-intel-helped-ukraine-sink-russian-flagship-moskva-officials-say-rcna27559.

Docherty, Bonnie. "Losing Humanity: The Case against Killer Robots." *Human Rights Watch*, November 19, 2012. https://www.hrw.org/report/2012/11/19/losing-humanity/case-against-killer-robots.

Edmonds, Jeffrey A., and Samuel Bendett. "Russia's Use of Uncrewed Systems in Ukraine." CNA Research Memorandum, March 15, 2023. https://www.cna.org/reports/2023/05/russias-use-of-drones-in-ukraine.

Eslami, Mohammad. "Iran's Drone Supply to Russia and Changing Dynamics of the Ukraine War." *Journal for Peace and Nuclear Disarmament* 5, no. 2 (November 20, 2022): 507–18. https://doi.org/10.1080/25751654.2022.2149077.

European Union Aviation Safety Agency. "Specific Operations Risk Assessment (SORA)." European Union Aviation Safety Agency, February 1, 2024. https://www.easa.europa.eu/en/domains/civil-drones-rpas/specific-category-civil-drones/specific-operations-risk-assessment-sora.

Fox, Amos C. "Reflections on Russia's 2022 Invasion of Ukraine: Combined Arms Warfare, the Battalion Tactical Group and Wars in a Fishbowl." AUSA, September 29, 2022. https://www.ausa.org/publications/reflections-russias-2022-invasion-ukraine-combined-arms-warfare-battalion-tactical.

Frąckiewicz, Marcin. "The Future of Drone Warfare: The Sky is the Limit," ΔΥΝΑΜΙΚΕΣ ΕΙΔΗΣΕΙΣ, April 25, 2023. https://ts2.space/en/the-future-of-drone-warfare-the-sky-is-the-limit/.

Freedberg, Sydney J. Jr. "Dumb and Cheap: When Facing Electronic Warfare in Ukraine, Small Drones' Quantity Is Quality." *Breaking Defense* (blog), June 13, 2023. https://breakingdefense.sites.breakingmedia.com/2023/06/dumb-and-cheap-when-facing-electronic-warfare-in-ukraine-small-drones-quantity-is-quality/.

Freedberg, Sydney J. Jr. "How Not to Innovate: Russia Plays Catch-up to Ukraine on Drones." *Breaking Defense* (blog), May 30, 2023. https://breakingdefense.sites.breakingmedia.com/2023/05/how-not-to-innovate-russia-plays-catch-up-to-ukraine-on-drones/.

Gagne, Danielle. "Stemming the Tide of Destruction: How Drones Are Saving Lives in Ukraine – Volatus," April 25, 2022. https://volatusaerospace.com/drone_network_news/how-drones-in-ukraine-save-lives/.

GDC. "Ukraine Started Mass Producing UJ-26 Beaver Deep Strike Kamikaze Drones." *Global Defense Corp* (blog), January 10, 2024. https://www.globaldefensecorp.com/2024/01/11/ukraine-started-mass-producing-uj-26-beaver-deep-strike-kamikaze-drones/.

Goldfarb, Avi, and Jon R. Lindsay, "Prediction and Judgement: Why Artificial Intelligence Increases the Importance of Humans in War," *International Security* 46, no. 3. Winter 2021-2022: 7-50.

Gosselin-Malo, Elisabeth. "Latvia's Atlas Dynamics to Open Drone Production Plant in Ukraine." *Defense News*, December 23, 2022. https://www.defensenews.com/unmanned/2022/12/23/latvias-atlas-dynamics-to-open-drone-production-plant-in-ukraine/.

Gosselin-Malo, Elisabeth, and Vivienne Machi. "Greece Picks Safran's Patroller Drones as French Industry Deepens Ties." *Defense News*, June 23, 2023. https://www.defensenews.com/unmanned/2023/06/23/greece-picks-safrans-patroller-drones-as-french-industry-deepens-ties/.

Government of the Czech Republic. "Czechia Sends Hundreds of Heavy Military Systems Worth Tens of Billions to Ukraine during the First Year of Russian Invasion." Vlada, February 23, 2023. https://vlada.gov.cz/en/media-centrum/tiskove-zpravy/czechia-sends-hundreds-of-heavy-military-systems-worth-tens-of-billions-to-ukraine-during-the-first-year-of-russian-invasion-203252/.

Government of the Netherlands. "Dutch Aid for Ukraine: From Day to Day." Onderwerp. Government of the Netherlands. Ministerie van Algemene Zaken, November 6, 2023. https://www.government.nl/topics/russia-and-ukraine/dutch-aid-for-ukraine.

Greenwood, Faine. "Drones in the Ukraine War: April 3rd to April 11th, 2022." Substack newsletter. *Little Flying Robots* (blog), April 12, 2022. https://faineg.substack.com/p/drones-in-the-ukraine-war-april-3rd.

Greenwood, Faine. "The Drone War in Ukraine Is Cheap, Deadly, and Made in China." *Foreign Policy* (blog), March 28, 2024. https://foreignpolicy.com/2023/02/16/ukraine-russia-war-drone-warfare-china/.

Hambling, David. "Could Small Drones Really Replace Artillery?" *Forbes*, August 16, 2023. https://www.forbes.com/sites/davidhambling/2023/08/16/could-small-drones-really-replace-artillery/.

Hambling, David. "Russian Volunteer Group Claims to Make 1,000 FPV Kamikaze Drones a Day." *Forbes*, December 5, 2023. https://www.forbes.com/sites/davidhambling/2023/12/05/russian-volunteer-group-making-a-thousand-fpv-kamikaze-drones-each-day/?sh=1a248e5511ec.

Hambling, David. "Ukrainian AI Attack Drones May Be Killing without Human Oversight." *New Scientist*, October 13, 2023. https://www.newscientist.com/article/2397389-ukrainian-ai-attack-drones-may-be-killing-without-human-oversight/.

Harding, Luke, and Pjotr Sauer. "Ukraine Levels up the Fight with Drone Strikes Deep into Russia." *The Guardian*, January 27, 2024, sec. World news. https://www.theguardian.com/world/2024/jan/27/ukraine-levels-up-the-fight-with-drone-strikes-deep-into-russia.

Harper, Jon. "2022 in Review: Ukraine Serving as Proving Ground for New – and Sometimes Secretive – US Defense Tech." *DefenseScoop* (blog), December 30, 2022. https://defensescoop.com/2022/12/29/2022-in-review-ukraine-serving-as-proving-ground-for-new-and-sometimes-secretive-us-defense-tech/.

Hartung, William D. "Beware of Pentagon Techno-Enthusiasm." *Defense One*, August 31, 2023. https://www.defenseone.com/ideas/2023/08/beware-pentagon-techno-enthusiasm/389885/.

Hartung, William D. "How Pentagon Contractors Are Cashing in on the Ukraine Crisis." Quincy Institute for Responsible Statecraft, April 17, 2022. https://quincyinst.org/2022/04/17/how-pentagon-contractors-are-cashing-in-on-the-ukraine-crisis/.

Heikkilä, Melissa. "Why Business Is Booming for Military AI Startups." *MIT Technology Review*, July 7, 2023. https://www.technologyreview.com/2022/07/07/1055526/why-business-is-booming-for-military-ai-startups/.

Heller, Kevin Jon. "The Concept of 'The Human' in the Critique of Autonomous Weapons | Harvard National Security Journal." *Harvard Law School National Security Journal* 15 (December 15, 2023). https://harvardnsj.org/2023/12/15/the-concept-of-the-human-in-the-critique-of-autonomous-weapons/.

Horowitz, Michael. "The Pentagon Is Already Testing Tomorrow's AI-Powered Swarm Drones, Ships." *Defense One*, January 22, 2024. https://www.defenseone.com/technology/2024/01/pentagon-already-testing-tomorrows-ai-powered-swarm-drones-ships/393528/?oref=defenseone_today_nl&utm_source=Sailthru&utm_medium=email&utm_campaign=Defense%20One%20Today:%20January%2023%2C%202024&utm_term=newsletter_d1_today.

Hudson, John, and Kostiantyn Khudov. "The War in Ukraine Is Spurring a Revolution in Drone Warfare Using AI." *The Washington Post*, July 26, 2023, sec. Europe. https://www.washingtonpost.com/world/2023/07/26/drones-ai-ukraine-war-innovation/.

Hunter, Cameron, and Bleddyn E. Bowen. "We'll Never Have a Model of an AI Major-General: Artificial Intelligence, Command Decisions, and Kitsch Visions of War." *Journal of Strategic Studies* 47, no. 1 (August 7, 2024): 116-46. https://doi.org/10.1080/01402390.2023.2241648.

Images, Baykar Press Office/dia images via Getty Images-Baykar Press Office via Getty. "Saudi Arabia Agrees to Produce Turkey's Baykar Drones," *Al-Monitor* (August 7, 2023). https://www.al-monitor.com/originals/2023/08/saudi-arabia-agrees-produce-turkeys-baykar-drones.

Jager, Jeff. "Challenges of Mechanized and Combined Arms Warfare: Lessons for Ukraine from Syria and Iraq." Middle East Institute, February 22, 2023. https://www.mei.edu/publications/challenges-mechanized-and-combined-arms-warfare-lessons-ukraine-syria-and-iraq.

Jahanbani, Nakissa, Muhammad Naijar, Benjamin Johnson, Caleb Benjamin, and Muhammad Al-Ubaydi. "Iranian Drone Proliferation Is Scaling up and Turn-

ing More Lethal." *War on the Rocks*, September 8, 2023. https://warontherocks.com/2023/09/iranian-drone-proliferation-is-scaling-up-and-turning-more-lethal/.

Johnson, James. "Artificial Intelligence and Future Warfare: Implications for International Security." *Defense & Security Analysis* 35, no. 2 (April 24, 2019): 147-69. https://doi.org/10.1080/14751798.2019.1600800.

Jones, Mared Gwyn. "UK and Latvia Lead Coalition to Provide Thousands of Drones to Ukraine." *Euronews*, February 15, 2024. https://www.euronews.com/my-europe/2024/02/15/uk-and-latvia-lead-coalition-to-provide-thousands-of-drones-to-ukraine.

Kantchev, Georgi. "Russia's Economy Goes All in on War." *The Wall Street Journal*, October 6, 2023. https://www.wsj.com/world/russia/putin-redirects-russias-economy-to-war-production-1e14265f.

Keller, Jared. "Ukrainian Drones Are Making Life Hell for Russian Troops in Crimea." *Task & Purpose*, December 15, 2022. https://taskandpurpose.com/news/ukrainian-drones-crimea-warfare/.

Khurshudyan, Isabelle, Paul Sonne, Serhiy Morgunov, and Kamila Hrabchuk. "Inside the Ukrainian Counteroffensive That Shocked Putin and Reshaped the War." *The Washington Post*, December 29, 2022. https://www.washingtonpost.com/world/2022/12/29/ukraine-offensive-kharkiv-kherson-donetsk/.

Kiel Institute for World Economy. "Ukraine Support Tracker – A Database of Military, Financial and Humanitarian Aid to Ukraine." Kiel Institute, December 7, 2023. https://www.ifw-kiel.de/topics/war-against-ukraine/ukraine-support-tracker/.

Konaev, Margarita. "Tomorrow's Technology in Today's War: The Use of AI and Autonomous Technologies in the War in Ukraine and Implications for Strategic Stability." *CNA Research Memorandum*, September 2023.

Kramer, Erik, and Paul Schneider. "What the Ukrainian Armed Forces Need to Do to Win." *War on the Rocks*, June 2, 2023. https://warontherocks.com/2023/06/what-the-ukrainian-armed-forces-need-to-do-to-win/.

Kryvosheiev, Margaryta Khvostova, Dmytro. "The Kyiv Sanctuary: Building the Ukrainian Defence against Russian Missiles." European Council of Foreign Relations, June 8, 2023. https://ecfr.eu/article/the-kyiv-sanctuary-building-the-ukrainian-defence-against-russian-missiles/.

Kunertova, Dominika. "Drones Have Boots: Learning from Russia's War in Ukraine." *Contemporary Security Policy* 44, no. 4 (October 4, 2023): 576-91. https://doi.org/10.1080/13523260.2023.2262792.

Kunertova, Dominika. "The War in Ukraine Shows the Game-Changing Effect of Drones Depends on the Game." *Bulletin of the Atomic Scientists* 79, no. 2 (March 4, 2023): 95-102. https://doi.org/10.1080/00963402.2023.2178180.

Le Monde. "France and Italy Will Send Ukraine MAMBA Missile Systems, Say French Officials." *Le Monde.Fr*, February 3, 2023. https://www.lemonde.fr/en/international/article/2023/02/03/france-and-italy-will-send-ukraine-mamba-missile-systems-say-french-officials_6014333_4.html.

Lee, Lloyd. "Ukraine Is Thinking More like Silicon Valley to Defend Itself against Russia's Electronic Warfare." *Business Insider*, November 20, 2023. https://www.businessinsider.com/ukraine-silicon-valley-start-up-combat-russian-electronic-warfare-jamming-2023-11.

Lee, Yimou, James Pomfret, and David Lague. "Special Report-Inspired by Ukraine War, Taiwan Launches Drone Blitz to Counter China | Reuters." *Reuters*, July 21, 2023. https://www.reuters.com/article/us-china-tech-taiwan-idUSL4N39714X/.

Lipton, Eric. "A.I. Brings the Robot Wingman to Aerial Combat." *The New York Times*, August 27, 2023, sec. U.S. https://www.nytimes.com/2023/08/27/us/politics/ai-air-force.html.

Lister, Tim, Frederik Pleitgen, and Konstantin Hak. "'The Enemy Is Always Looking for Us': Hidden in the Forest, Ukraine's Drone Operators Are Crucial to the Eastern Battle." *CNN*, January 30, 2023. https://www.cnn.com/2023/01/30/europe/ukraine-drone-operators-forest-kreminna-intl-cmd/index.html.

Lowther, Adam, and Mahube E. Siddiki. "Combat Drones in Ukraine." *Air & Space Operations Review* 1, no. 4 (Winter 2022): 13.

Luzin, Pavel. "Russian UAVs: What Has Gone Wrong?" The Jamestown Foundation, November 11, 2022. https://jamestown.org/program/russian-uavs-what-has-gone-wrong/.

Marcinek, Krystyna, and Eugeniu Han. "Russia's Asymmetric Response to 21st Century Strategic Competition: Robotization of the Armed Forces." RAND Corporation, March 13, 2023. https://www.rand.org/pubs/research_reports/RRA1233-5.html.

Masters, Jonathan, and Will Merrow. "How Much Aid Has the U.S. Sent Ukraine? Here Are Six Charts." Council on Foreign Relations. Accessed March 21, 2024. https://www.cfr.org/article/how-much-aid-has-us-sent-ukraine-here-are-six-charts.

McCrory, Duncan. "Electronic Warfare in Ukraine: Preliminary Lessons for NATO Air Power Capability Development," Transforming Joint Air and Space Power, no. 36 (Summer 2023): 69-74.

McDermott, Roger N. "Russia's Electronic Warfare Capabilities to 2025." *International Centre for Defence and Security*, September 2017. https://icds.ee/wp-content/uploads/2018/ICDS_Report_Russias_Electronic_Warfare_to_2025.pdf.

McDermott, Roger N. "Russia's Electronic Warfare Capabilities to 2025: Challenging NATO in the Electromagnetic Spectrum." Republic of Estonia, Ministry of Defence: International Centre for Defence and Security, September 2017. https://icds.ee/wp-content/uploads/2018/ICDS_Report_Russias_Electronic_Warfare_to_2025.pdf.

Meeting of the CCW Group of Governmental Experts on Emerging Technologies in the Area of Lethal Autonomous Weapons Systems. "Convention on Certain Conventional Weapons – Group of Governmental Experts on Lethal Autonomous Weapons Systems (2023)." Accessed March 22, 2024. https://meetings.unoda.org/meeting/67246/statements.

Melchior, Jillian Kay. "Drones Are Giving Ukraine a Wartime Edge." *The Wall Street Journal*, February 23, 2023, sec. Opinion. https://www.wsj.com/articles/drones-are-giving-ukraine-a-wartime-edge-homemade-dji-china-russia-tanks-weaponry-invasion-civilian-volunteer-russian-occupation-5c0bab55.

Mitzer, Stijn, and Joost Oliemans. "An International Export Success: Global Demand for Bayraktar Drones Reaches All Time High." *Oryx* (blog), September 2, 2022. https://www.oryxspioenkop.com/2021/09/an-international-export-success-global.html.

Mortimer, Gay. "The History and Effectiveness of the Bayraktar TB2 Drone in Ukraine." *sUAS News – The Business of Drones*, June 26, 2023. https://www.suasnews.com/2023/06/the-history-and-effectiveness-of-the-bayraktar-tb2-drone-in-ukraine/.

Mozur, Paul, Aaron Krolik, and Keith Bradsher. "As War in Ukraine Grinds On, China Helps Refill Russian Drone Supplies." *The New York Times*, March 21, 2023, sec. Business. https://www.nytimes.com/2023/03/21/business/russia-china-drones-ukraine-war.html.

Muravska, Julia. "Drones and Defence Innovation in Ukraine: Consolidating Wartime Ingenuity." King's College London, November 29, 2022. https://www.kcl.ac.uk/drones-and-defence-innovation-in-ukraine-consolidating-wartime-ingenuity.

Musumeci, Natalie. "Ukraine Is Using $100,000 Octocopter Drones to Destroy Russian Tanks and Artillery Worth Millions, Even in the Dead of Night, Operator Says." *Business Insider*, October 6, 2023. https://www.businessinsider.com/ukraine-using-octocopter-drones-to-destroy-russian-tanks-2023-10.

Newcome, Laurence R. *Unmanned Aviation: A Brief History of Unmanned Vehicles*. Barnsley, Pen and Sword Aviation, 2004.

Novikov, Illia. "Russian Drone Attack on a City in Western Ukraine Sparks an Inferno at a Warehouse and Kills 1." *AP News*, September 19, 2023, sec. World News. https://apnews.com/article/russia-ukraine-war-drone-attacks-lviv-warehouse-fire-1e7471f82a847d7f2933007d92812389.

Office of the Director of National Intelligence. "Deeper Looks: The Future of the Battlefield." Office of the Director of National Intelligence, March 2022. https://www.dni.gov/index.php/gt2040-home/gt2040-deeper-looks/future-of-the-battlefield.

Olearchyk, Romean. "Military Briefing: Russia Has the Upper Hand in Electronic Warfare with Ukraine." *Financial Times*, January 7, 2024. https://www.ft.com/content/a477d3f1-8c7e-4520-83b0-572ad674c28e.

Ozberk, Tayfun. "Turkey's Havelsan Tests Robots, Drone Swarm for Digital Troop Concept." *Defense News*, August 24, 2023, sec. Unmanned. https://www.defensenews.com/unmanned/2023/08/24/turkeys-havelsan-tests-robots-drone-swarm-for-digital-troop-concept/.

Payne, Kenneth. *I, Warbot: The Dawn of Artificially Intelligent Conflict*. Oxford University Press, 2021. https://doi.org/10.1093/oso/9780197611692.001.0001.

Pearson, Lee. "Developing the Flying Bomb." In *Naval Aviation in World War I*. Washington D.C., Chief of Naval Operations, 1969.

Permanent Mission of France to the United Nations in New York. "France Supports Ukraine in Exercising Its Right to Self-Defense." France ONU, September 12, 2023. https://onu.delegfrance.org/nouvelle-traduction-france-supports-ukraine-in-exercising-its-right-to-self.

Pettyjohn, Stacie. "Evolution Not Revolution: Drone Warfare in Russia's 2022 Invasion of Ukraine." Centre for New American Security, February 2024. https://s3.us-east-1.amazonaws.com/files.cnas.org/documents/CNAS-Report-Defense-Ukraine-Drones-Final.pdf.

Pickrell, Ryan. "'Top Tanks Worth Millions and Other Expensive Heavy Armor Are Being Hunted in Ukraine by Cheap Exploding Drones Worth Only a Few Hundred Bucks." *Business Insider*, August 8, 2023. https://www.businessinsider.com/ukraine-war-top-tanks-taken-out-by-cheap-hobby-drones-2023-8.

Ragip, Soylu. "Ukrainian TB2 Bayraktar Drone 'Bombed Oil Depots Deep inside Russia.'" Middle East Eye, April 27, 2022. https://www.middleeasteye.net/news/russia-ukraine-tb2-bayraktar-drones-said-bombed-oil-depots.

Rainy, James, and Laura Potter. "Delivering the Army of 2030." *War on the Rocks*, August 6, 2023. https://warontherocks.com/2023/08/delivering-the-army-of-2030/.

Regencia, Ted, Priyanka Shankar, and Usaid Siddiqui. "Russia-Ukraine War Updates: Moscow, Kyiv Trade Drone Attacks." *Al Jazeera*, September 26, 2023. https://www.aljazeera.com/news/liveblog/2023/9/26/russia-ukraine-war-live-several-dead-in-air-strikes-on-odesa.

Renic, Neil C. "Remote Warfare: Drivers, Limits, Challenges." In *Routledge Handbook of the Future of Warfare*, 1st ed., 190-200. Routledge, 2024. https://doi.org/10.4324/9781003299011-21.

Renic, Neil, and Elke Schwarz. "Crimes of Dispassion: Autonomous Weapons and the Moral Challenge of Systematic Killing." *Ethics & International Affairs* 37, no. 3 (December 1, 2023): 321-43. https://doi.org/10.1017/S0892679423000291.

Reuters. "Russian Oil Facilities Hit by Drone Attacks, Fires | Reuters." *Reuters*, January 29, 2024. https://www.reuters.com/markets/commodities/russian-oil-facilities-hit-by-drone-attacks-fires-2024-01-29/.

Reynolds, Ian, and Ozan Ahmet Cetin. "War Is Messy. AI Can't Handle It." *Bulletin of the Atomic Scientists* (blog), August 14, 2023. https://thebulletin.org/2023/08/war-is-messy-ai-cant-handle-it/.

Robertson, Noah. "Counter-Drone Tech Need like That of 155mm Shells: Pentagon's LaPlante." *Defense News*, December 4, 2023. https://www.defensenews.com/pentagon/2023/12/04/counter-drone-tech-need-like-that-of-155mm-shells-pentagons-laplante/.

Rosoboronexport. "Strelets (Index 83t215i): Reconnaissance, Control and Communications Complex." Catalog Rosoboronexport, n.d. http://roe.ru/eng/catalog/land-forces/military-communications-equipment-and-automated-control-systems/automated-control-systems/strelets/.

Rubin, Uzi. "Russia's Iranian-Made UAVs: A Technical Profile." RUSI, March 20, 2024. https://rusi.orghttps://rusi.org.

Schaub, Gary, and Jens Wenzel Kristoffersen. "In, On or Out of the Loop? Denmark and Autonomous Weapons Systems." *Centre for Military Studies*, February 2017.

Schmidt, Eric. "Ukraine Is Losing the Drone War." *Foreign Affairs*, January 22, 2024. https://www.foreignaffairs.com/ukraine/ukraine-losing-drone-war-eric-schmidt.

Schmitt, Eric, and Helene Cooper. "Ukrainian Troops Trained by the West Stumble in Battle." *The New York Times*, August 2, 2023, sec. U.S. https://www.

nytimes.com/2023/08/02/us/politics/ukraine-troops-counteroffensive-training.html.

Sebastian, Clare. "Ukraine Makes New Push to Defeat Russia's Electronic Warfare." *CNN*, November 29, 2023. https://www.cnn.com/2023/11/29/europe/ukraine-russia-electronic-warfare-intl-cmd/index.html.

Shashank, Joshi. "The War in Ukraine Shows How Technology Is Changing the Battlefield." *The Economist*, July 3, 2023. https://www.economist.com/special-report/2023/07/03/the-war-in-ukraine-shows-how-technology-is-changing-the-battlefield.

Sherman, Jason. "Drone-on-Drone Combat in Ukraine Marks a New Era of Aerial Warfare." *Scientific American*, April 3, 2023. https://www.scientificamerican.com/article/drone-on-drone-combat-in-ukraine-marks-a-new-era-of-aerial-warfare/.

Shoaib, Alia. "Why Ukraine Is Able to Embarrass Russia's Air Defense Systems, among the Most Advanced in the World, with Small Drones." *Business Insider*, September 2, 2023. https://www.businessinsider.com/russia-ukraine-war-advanced-air-defenses-failed-drone-strikes-2023-9.

Simoens, Tom. "Combined Arms Warfare as The Key to Success on The Contemporary Battlefield?" *TDHJ.Org* (blog), December 1, 2022. https://tdhj.org/blog/post/combined-arms-warfare-success-battlefield/.

Singh, Ishveena. "Finnish Volunteers Deliver 140 DJI Mavic Mini Drones to Ukraine Military." DroneDJ, March 3, 2022. https://dronedj.com/2022/03/03/finland-140-dji-mini-drone-ukraine-military/.

Singh, Mandeep. "Russian Electronic Warfare in Ukraine 2022-2023 – Indian Defence Review." *India Defence Review*, July 7, 2023. https://www.indiandefencereview.com/news/russian-electronic-warfare-in-ukraine-2022-2023/.

Skove. "UK Sees 'Incredible Acceleration' in Military Capabilities from Ukraine War." *Defense One*, November 14, 2023. https://www.defenseone.com/threats/2023/11/uk-gains-incredible-acceleration-military-capabilities-ukraine-war/392005/.

Spinetta, Lawrence. "Secrets behind the Surprising Rise of Drones." HistoryNet, June 20, 2019. https://www.historynet.com/the-rise-of-unmanned-aircraft/.

Sprenger, Sebastian. "Hungary Orders Hero Kamikaze Drones from Rheinmetall-UVision Venture." *Defense News*, July 20, 2023. https://www.defensenews.com/global/europe/2023/07/20/hungary-orders-hero-kamikaze-drones-from-rheinmetall-uvision-venture/.

Statement by Denmark. "CCW Informal Meeting of Experts on LAWS," April 13, 2015. https://www.reachingcriticalwill.org/images/documents/Disarma-

ment-fora/ccw/2015/meeting-experts-laws/statements/13April_Denmark.pdf.

Stevenson, Wendell. "The 'Crazy Professors' Making Drones for Ukraine." *The Economist*, August 4, 2023. https://www.economist.com/1843/2023/08/04/the-crazy-professors-making-drones-for-ukraine.

Stone, Mike. "Ukraine Asks U.S. for Big Drones, Hoping to Overcome Opposition." *Reuters*, November 15, 2022, sec. Aerospace & Defense. https://www.reuters.com/business/aerospace-defense/ukraine-asks-us-big-drones-hoping-overcome-opposition-2022-11-15/.

The British Army. "Army Announces New Way of Winning Future Wars." The British Army, September 16, 2023. https://www.army.mod.uk/news-and-events/news/2023/09/army-announces-new-way-of-winning-future-wars/.

The Economist. "How Cheap Drones Are Transforming Warfare in Ukraine." *The Economist*, February 5, 2024. https://www.economist.com/interactive/science-and-technology/2024/02/05/cheap-racing-drones-offer-precision-warfare-at-scale.

The Economist. "How Could FPV Drones Change Warfare?" *The Economist*, August 4, 2023. https://www.economist.com/the-economist-explains/2023/08/04/how-could-fpv-drones-change-warfare?utm_medium=social-media.content.np&utm_source=twitter&utm_campaign=editorial-social&utm_content=-discovery.content.

The Economist. "Killer Drones Pioneered in Ukraine Are the Weapons of the Future." *The Economist*, August 4, 2023. https://www.economist.com/leaders/2024/02/08/killer-drones-pioneered-in-ukraine-are-the-weapons-of-the-future.

The Economist. "Ukraine's Commander-in-Chief on the Breakthrough He Needs to Beat Russia." *The Economist*, November 1, 2023. https://www.economist.com/europe/2023/11/01/ukraines-commander-in-chief-on-the-breakthrough-he-needs-to-beat-russia.

The Russian Government. "Meeting of the Coordination Council on the Needs of the Russian Federation Armed Forces, Other Troops, Military Units and Bodies." The Russian Government, December 5, 2023. http://government.ru/en/news/50324.

Thurnher, Jeffrey S. "Legal Implications of Fully Autonomous Targeting." *Joint Force Quarterly* 67, March 8, 2017. http://ndupress.ndu.edu/Portals/68/Documents/jfq/jfq-67/JFQ-67_77-84_Thurnher.pdf.

Tirpak, John. "Ukraine War Shows Importance of Counter-UAS, Air Defense, Distributed Ops to Air Warfare." *Air & Space Forces Magazine*, November 15,

2022. https://www.airandspaceforces.com/ukraine-war-shows-importance-of-counter-uas-air-defense-distributed-ops-to-air-warfare/.

Triebert, Christiaan, Haley Willis, Yelyzaveta Kovtun, and Alexander Cardia. "Ukraine's Other Counteroffensive: Drone Attacks on Russian Soil." *The New York Times*, July 31, 2023, sec. World. https://www.nytimes.com/2023/07/31/world/europe/ukraine-drone-strikes-russia.html.

Trofimov, Yaroslav. "Drones Everywhere: How the Technological Revolution on Ukraine Battlefields Is Reshaping Modern Warfare." *The Wall Street Journal*, September 28, 2023. https://www.wsj.com/world/drones-everywhere-how-the-technological-revolution-on-ukraine-battlefields-is-reshaping-modern-warfare-bf5d531b.

United States Agency for International Development. "USAID Delivers Skydio Autonomous Camera Drones to Ukraine to Document War Crimes." U.S. Agency for International Development, July 27, 2023. https://www.usaid.gov/news-information/press-releases/jul-27-2023-usaid-delivers-skydio-autonomous-camera-drones-ukraine-document-war-crimes.

United States Marine Corps. "Force Design 2030: Annual Update." United States Marine Corps, June 2023. https://www.marines.mil/Portals/1/Docs/Force_Design_2030_Annual_Update_June_2023.pdf.

U.S. Department of Defense. "DoD Announces Update to DoD Directive 3000.09, 'Autonomy in Weapon Systems.'" U.S. Department of Defense, January 25, 2023. https://www.defense.gov/News/Releases/Release/Article/3278076/dod-announces-update-to-dod-directive-300009-autonomy-in-weapon-systems/https%3A%2F%2Fwww.defense.gov%2FNews%2FReleases%2FRelease%2FArticle%2F3278076%2Fdod-announces-update-to-dod-directive-300009-autonomy-in-weapon-systems%2F.

Veilleux-Lepage, Yannick, and Emil Archambaut. "A Comparative Study of Non-State Violent Drone Use in the Middle East." International Centre for Counter-Terrorism - ICCT, December 9, 2022. https://www.icct.nl/index.php/publication/comparative-study-non-state-violent-drone-use-middle-east.

Walker, Rosling. "An Evaluation of the Russian Arrangement of Military Operations during the First Phase of the Russo-Ukrainian War | Future Forge." *The Forge*, 2022. https://theforge.defence.gov.au/war-college-papers-2022/evaluation-russian-arrangement-military-operations-during-first-phase-russo-ukrainian-war.

Walton, Ethan. "Here's the Counter-Drone Platforms Now Deployed in Ukraine." C4ISRNet, November 21, 2023. https://www.c4isrnet.com/opinion/2023/11/21/heres-the-counter-drone-platforms-now-deployed-in-ukraine/.

Ward, Alexander, and Lee Hudson. "Why the Gray Eagle Still Hasn't Landed in Ukraine." *Politico*, March 20, 2024. https://www.politico.com/newsletters/national-security-daily/2022/08/09/why-the-gray-eagle-still-hasnt-landed-in-ukraine-00050499.

Watling, Jack, and Nick Reynold. "Meatgrinder: Russian Tactics in the Second Year of Its Invasion of Ukraine." RUSI, May 19, 2023. https://rusi.orghttps://rusi.org.

Wyrwal, Marcin. "War in Ukraine: How Artificial Intelligence Is Killing Russians." Onet, July 13, 2022. https://wiadomosci.onet.pl/tylko-w-onecie/rozwiazali-problem-armii-ukrainy-ich-pomysl-okazal-sie-dla-rosjan-zabojczy/pkzrk0z.

Yusif, E. "Drone Warfare in Ukraine: Understanding the Landscape." *Stimson Center* (blog), June 30, 2022. https://www.stimson.org/2022/drone-warfare-in-ukraine-understanding-the-landscape/.

Zaluzhny, Valery. "Modern Positional Warfare and How to Win It." UDC 355, n.d. https://infographics.economist.com/2023/ExternalContent/ZALUZHNYI_FULL_VERSION.pdf.

Annex I: Technology Overview: Military and Commercial-Grade Drones

Military-Grade Drones[196]

Ukrainian

Drone	Primary missions	Developer and country	Estimated Cost (USD)
Athlon Avia A1-CM Furia	ISR/LM	Athlan Avia, Ukraine	$25,000
Bayraktar TB2	ISR/LM	Baykar Makina, Turkey	$5,000,000
Golden Eagle	ISR	Teal Drones, USA	$7,450
Leleka-100 Stork	ISR/LM	DeViRo, Ukraine	$48,700
Mini-Bayraktar	ISR	Baykar Makina, Turkey	$1,000,000
Mugin-5	ISR/LM	Mugin UAV, China	$9,500
Phoenix Ghost	ISR/LM	Aevex Aerospace, USA	$400
Punisher	ISR/LM	UA Dynamics, Ukraine	$50,000
Quantum Systems Vector	ISR	Quantum Systems, Germany	$195,600
R18	ISR/LM	Aerorozvidka, Ukraine	$100,000
RQ-20 Puma	ISR	AeroVironment, USA	$250,000

196. This is a non-exhaustive list of drone models. Our intention is simply to highlight the large and growing number of in-use models in the conflict.

RQ-4 Global Hawk	ISR	Nothrup Grumman, USA	$130,000,000
Skydio X2	ISR	Skydio, USA	$11,000
Spectator-M1	ISR	VAT S.P. Korolev Meridian JSC, Ukraine	Unknown
Switchblade 300	LM	AeroVironment, USA	$6,000
Switchblade 600	LM	AeroVironment, USA	$58,000
Tu-143 Reis	ISR	Tupolev, USSR	Unknown
UJ-22 Airborne	ISR/LM	Ukrjet, Ukraine	Unknown
WB FlyEye	ISR	WB Electronics, Poland	$26,500
WB Group Warmate	ISR/LM	WB Electronics, Poland.	$12,000

Russian

Drone	Primary missions	Developer and country	Estimated Cost (USD)
Aerial Target E-95M	ISR	Enics Areo, Russia	Unknown
Eleron-3	ISR	Enics Areo, Russia	$100,000
Forpost	ISR	Israel Aerospace Industries, Israel/ Russian Armed Forces	$6,000,000
HESA Shahed 131	LM	Shahed Aviation Industries, Iran	$20,000-30,000
HESA Shahed 136	LM	Shahed Aviation Industries, Iran	$20,000-30,000
Izhmash Granat-4	ISR	Izmash Unmanned Systems, Russia	Unknown
KUB-BLA	ISR/LM	Kalashnikov, Russia	$160,000
Kartograf	ISR	Special Technology Center, Russian Armed Forces, Russia	Unknown
KBLA-IVT	ISR	Tekhodinamika JSC, Russia	Unknown
Korsar	ISR	OKB Luch, Russia	Unknown

Kvazimactha	ISR	Russian Armed Forces, Russia	Unknown
Orion-E	ISR/LM	Kronsthadt Group, Russia	Unknown
Orlan-10	ISR/LM	Special Technology Center, Russian Armed Forces, Russia	$87,000-120,000
Orlan-30	ISR	Special Technology Center, Russian Armed Forces, Russia	$87,000-120,000
Prohod-1	ISR	High Precision Weapons JSC, Russia	Unknown
R-2200	ISR	Rus Design Bureau, Russia	Unknown
Sukhoi S-70 Okthonik-B	ISR	Sukhoi (Rostoc Group), Russia	Unknown
Volk-18	ISR/LM	Almaz-Antey, Russia	Unknown
Zala KYB	LM	Zala Areo Group, Russia	Unknown
Zala-Lancet	LM	Zala Areo Group, Russia	$35,000

Commercial-Grade Drones

Ukrainian			
Drone	Primary missions	Developer and country	Estimated Cost (USD)
Autel Evo II Series	ISR/LM	Autel Robotics, USA	$6,000-127,000
DJI Mavic Series	ISR/LM	Shenzhen DJI Sciences and Technologies, Ltd., China	$12,000-45.000
PD-1 People's Drone	ISR	UkrSpecSystems, Ukraine	$453,000
Quantex Mapper	ISR	AeroVironment	$6,500
SkyRanger R60	ISR	Aereyon Labs	$28,000

Bivoj	ISR	Anonymous Drone Developer	$1,300,000
ScanEagle	ISR	Boeing Insitu, USA	$3,200,000
THeMIS	BA	Milrem, Estonia	Unknown
Black Hornet Nano	ISR	Prox Dynamics AS, Norway	$195,000

Russian

Drone	Primary missions	Developer and country	Estimated Cost (USD)
DJI Mavic Series	ISR/LM	Shenzhen DJI Sciences and Technologies Ltd., China	$12,000-45,000
Zala 421	ISR	Zala Areo Group, Russia	Unknown
Zastava	UAV/ISR	URal Works of Civil Aviation JSC, Russia	$200,000

ABOUT THE AUTHORS

Neil Renic, PhD, is a Researcher at the Centre for Military Studies at the University of Copenhagen. He is also a Fellow at the Institute for Peace Research and Security Policy (IFSH) and member of the International Committee for Robot Arms Control (ICRAC). Neil is a specialist on the changing character and regulation of armed conflict, and emerging military technologies.

Johan Gröne Christensen is a research assistant at the Centre for Military Studies at Copenhagen University. He mainly works on analyzing drones in modern warfare and Denmark's military cooperations in the wider European security order.

9 788757 461978