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THE DRONE REVOLUTION IN MILITARY AFFAIRS?

A THEORETICAL AND EMPIRICAL ASSESSMENT

According to the dominant wisdom, military unmanned aerial vehicles (UAVs, also known as drones) are transforming warfare. Allegedly easy and cheap to build as well as capable of outperforming existing weapon systems in several metrics, drones are thought to provide an offensive advantage in military operations, to level the playing field among major and minor actors and to turn conflict into long-range precision-strike engagements. If these understandings are correct, a new era of instability and conflict will soon emerge because of drones, with eventual repercussions also for the structure of the international system. In this article, we question this view. Building on Stephen Biddle's modern system of force employment, we argue that, starting from the 1970s, a second firepower revolution has dramatically increased the lethality of air warfare. The resulting hider-seeker competition between air forces and air defense has rewarded those who employ more effectively a set of tactics, techniques, procedures, technologies, and capabilities aimed at avoiding detection and at suppressing enemy fire while imposing enormous punishment on those who fail. We hypothesize that drones, rather breaking this system are just one of its many evolutions: since they are vulnerable to air-defense system and electronic warfare systems, and require the support of other assets, their effectiveness depends on their integration with the rest of the force structure. We test these two contending frameworks on three recent conflicts which saw extensive employment of drones: the civil wars in Libya and Syria as well as the 2020 "44 days war" over Nagorno-Karabakh. Available evidence shows that drones have not tilted the balance in favor of the offense; they have not reduced the gap between stronger and weaker actors; and they have not eclipsed close combat. While acknowledging the important role UAVs have come to play in recent conflicts, our analysis thus questions dominant narratives about an ensuing drone-drive revolution in military affairs.

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Over the past two decades, unmanned aerial vehicles (UAVs) have progressively become a constant feature of modern conflicts and if current trends continue, they will likely become even more important in future warfare.[1] The substitution of troops on the grounds with various types of robotic systems raises major ethical, legal, philosophical as well as political and military questions.[2] According to some, the emergence of drones is not just an instance of technological progress applied to military operations, but the beginning of a new era in world politics. So much so that some have spoken of an "unmanned revolution in military affairs."[3] The implications of this revolution are self-evident, as it would affect not only doctrines, organization and force structure, but also decide who wins and who loses in future conflicts as well as impact regional and international stability for the years to come.[4] According to existing understandings, the revolutionary nature of drone warfare stems from three key effects that this technology has on the employment for force. First, allegedly UAVs tilt the military balance in favor of the offense: thanks to their small size, slow speed and low altitude flight, drones are more difficult to detect than traditional military aircraft, and hence they can more easily penetrate air defense systems, thus

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[1] Matthew Fuhrmann and Michael C. Horowitz, "Droning On: Explaining the Proliferation of Unmanned Aerial Vehicles," *International Organization* Vol. 71, No. 2 (2017), 397-418; Michael C. Horowitz., Joshua A. Schwartz and Matthew Fuhrmann, "Who's Prone to Drone? A Global Time-Series Analysis of Armed Uninhabited Aerial Vehicle Proliferation," *Conflict Management and Peace Science* (online first view).

[2] P. W. Singer, *Wired for War: The Robotics Revolution and Conflict in the 21st Century* (New York: Penguin Press, 2009); and Stephen Bryen, "Armed Drones Revolutionizing the Future of War," *Asian Times* (December 9, 2020); Christopher Coker, *Warrior Geeks How 21st Century Technology is Changing the Way we Fight and Think About War* (London: Hurst Publishers, 2013); Gregoire Chamayou, A Theory of the Drone (New York, NY: The New Press, 2015); Peter L. Bergen and Daniel Rothenberg (eds), *Drone Wars: Transforming Conflict, Law, and Policy* (Cambridge: Cambridge University Press, 2014); Hugh Gusterson, *Drone: Remote Control Warfare* (Cambridge, MA: The MIT Press, 2016); Andreas Krieg and Jean-Marc Rickli, *Surrogate Warfare: The Transformation of War in the Twenty-First Century* (Washington, DC: Georgetown University Press, 2019); Michael J. Boyle, *The Drone Age: How Drone Technology Will Change War and Peace* (Oxford: Oxford University Press, 2020).

[3] See for example Adam N. Stulberg, "Managing the Unmanned Revolution in the U.S. Air Force," *Orbis* Vol. 51, No. 2 (March 2007), pp. 251–265.

[4] Jürgen Altmann and Frank Sauer, "Autonomous Weapon Systems and Strategic Stability," *Survival* Vol. 59, No. 5 (October-November 2017), pp. 117-142; Jason Lyall, "Drones Are Destabilizing Global Politics: Simple Vehicles Make Conflict Tempting and Cheap," *Foreign Affairs* (December 16, 2020).

facilitating offensive operations. Second, according to the conventional wisdom, drones would level the playing field in world politics: because of their low costs and limited technological sophistication, they are more accessible to weaker and resource-scarce actors, thus endowing them with the capabilities to fight also against major and wealthy powers. Finally, by enabling long-range, precision-strike, UAVs are thought to cancel close combat from the battlefield, thus relieving countries from the need to deploy troops on the ground.[5]

Prominent scholars and practitioners, in their examination of recent conflicts, have corroborated these intuitions. Some, for instance, describe drones performance in the 2020 Nagorno-Karabakh conflict between Azerbaijan and Armenia as a "magic bullet".[6] According to others, along the same lines, UAVs proved a "tactical game changer."[7] Echoing these view, the *Wall Street Journal* suggests that drones are "reshap[ing] battlefield and geopolitics."[8] Consistent with this perspective, the Hamburg-based German Institute for Defense and Strategic Studies concludes that German armed forces "would have hardly stood a chance" in a conflict with Azerbaijan, similar to the Armenia-Azerbaijan 2020 war.[9] Agnes Callamard and James Rogers go even one step further and maintain that the proliferation of increasingly capable drones will soon "help decide the fate of nations."[10]

If we are in fact at the outset of the drone revolution, as many believe, the theoretical and policy implications would be dramatic. First and foremost, since drones allegedly lower the entry barrier for the acquisition and possession of advanced military capabilities, century-old links

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[5] T. X. Hammes, "Droning America: The Tech Our Enemies Can Buy," *War on The Rocks* (13 October 2013); Noel Sharkey, "Drone Race Will Ultimately Lead To a Sanitized Factory of Slaughter," *The Guardian* (3 August 2012); Sarah Kreps and Micah Zenko, "The Next Drone Wars," Foreign Affairs 93, no. 2 (March/April 2014): 68–79.
[6] See David Hambling, "'The Magic Bullet' Drones Behind Azerbaijan's Victory Over Armenia," *Forbes* (Nov 10,2020).
[7] Arshaluys Mgdesyan, "Drones A Game Changer In Nagorno-Karabakh," *Eurasia Review* (November 2, 2020), https://www.eurasiareview.com/02112020-drones-a-gamechanger-in-nagorno-karabakh/.
[8] James Marson and Brett Forrest, "Armed Low-Cost Drones, Made by Turkey, Reshape Battlefields and Geopolitics," *The Wall Street Journal* (June 2, 2021), https://www.wsj.com/articles/armed-low-cost-drones-made-by-turkey-reshape-battlefields-and-geopolitics-11622727370?mod=e2fb&fbclid=IwAR2DHachMN0fG_JQb5dW_k85x2-cbOX4ClPse_bwlam9_Kf-OvLX2UWPh7Y.
[9] "Bundeswehr nicht gegen Angriffe von Kampfdrohnen gerüstet," *Die Zeit* (June 13, 2021), https://www.zeit.de/news/2021-06/13/analyse-bundeswehr-gegen-drohnen-unterlegen.
[10] Agnes Callamard and James Rogers, "We Need a New International Accord to Control Drone Proliferation," *Bulletin of Atomic Scientists* (December 1, 2020), https://thebulletin.org/2020/12/we-need-a-new-international-accord-to-control-drone-proliferation/.

between wealth and power might weaken or disappear, and thus we might be approaching a "new medievalism" in which a multitude of actors, whether states or non-states, have the capacity to wage war.[11] Second, and related, as Amy Zegart note, "because drones carry dramatically lower human and financial costs, they make it more politically feasible for states to 'keep shooting forever'."[12] As a result, diplomatic and political solutions to conflict will be increasingly more difficult to reach. Third, countries would have to significantly revise their defense policies. According to Ian Shaw, for instance, "large-scale ground wars are being eclipsed by fleets of weaponised drones."[13] Similarly, Francis Fukuyama suggests that "the use of drones is going to change the nature of land power" thus "undermin[ing] existing force structures."[14] T. X. Hammes goes one step further and argues that because of the drone revolution, "many states, and even insurgent or terrorist groups, will be able to project force at intercontinental range," and as a result, "opponents will have an increased ability to threaten intermediate [U.S.] bases" while a "larger number of weapons" will be able to "hit in-theater bases."[15] As a result, forward defense and, more generally, a global-reach defense posture will be increasingly difficult to maintain for the United States while all countries will have to restructure away their armed forces from very expensive and complex military platforms in favor of new, less sophisticated, and hence cheaper technologies such as drones.[16]

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[11] On new medievalism, see Hedley Bull, *The Anarchical Society: A Study of Order in World Politics* (Basingstoke: Palgrave, 2002), pp. 245–46.

[12] More specifically, Zegart explains, for "coercion, this means that threats from a drone state, if carried out, are more likely to be continued over the long term." Amy Zegart, "Cheap fights, Credible Threats: The Future of Armed Drones and Coercion", *Journal of Strategic Studies*, Vol. 43 (1) (February 28, 2018), p. 18. For a more general discussion, see also For a discussion, see for example Erik Gartzke, "Blood and Robots: How Remotely Piloted vehicles and Related Technologies Affect the Politics of Violence," *Journal of Strategic Studies* (2019).

[13] Ian G. R. Shaw, "Predator Empire: The Geopolitics of US Drone Warfare," *Geopolitics* Vol. 18, No. 3 (June 2013), pp. 536-559, https://doi.org/10.1080/14650045.2012.749241.

[14] Francis Fukuyama, "Droning On in the Middle East," *American Purpose* (April 5 2021), https://www.americanpurpose.com/blog/fukuyama/droning-on/.

[15] T. X. Hammes, "Technologies Converge and Power Diffuses: The Evolution of Small, Smart, and Cheap Weapons", *CATO Institute*, Policy Analysis No. 786 (January 27, 2016), https://www.cato.org/policy-analysis/technologies-converge-power-diffuses-evolution-small-smart-cheap-weapons#loss-of-immunity-to-attack

[16] For this suggestion, see for example, T. X. Hammes, "In an Era of Cheap Drones, US Can't Afford Exquisite Weapons," *DefenseOne* (January 19, 2016); and T. X. Hammes, "An End to Exquisite Weapons: We Might Not Need Such Big Platforms Anymore," *The National Interest* (July 26, 2020).

These views and concerns are legitimate, especially in light of the unprecedented technological transformation that we are experiencing.[17] However, as Stephen Biddle noted almost twenty years ago with respect to the debate on the revolution in military affairs (RMA), "[c]hange, of course, is inevitable. But so is continuity. And today's policy debate systematically exaggerates the former and slights the latter."[18] As we explain in this article, Biddle's considerations equally apply to the drone RMA: analysts, policy makers and scholars have generally neglected a constant feature of air warfare: the extreme lethality of air warfare. In this article, we adapt Biddle's modern system of force employment to drone warfare: we derive an alternative understanding in which drones, rather than a rupture with the past, are part of the evolution of air warfare and in particular of the "hider-seeker" competition between air defense and air penetration.[19] This competition, we maintain, rewards those who master the employment of a set of tactics, techniques, procedures, technologies, and capabilities aimed at limiting exposure to enemy fire, and, at the same time, imposes extremely high costs on those who fail.[20] This conceptual framework provides us with a null hypothesis against which to test the accepted wisdom, the drone revolution thesis. Moreover, in contrast to the drone revolution thesis, it suggests that drones have not altered the driving principles of modern air warfare, the need to avoid exposure to enemy fire. Thus, we hypothesize that drones, by themselves, do not produce the effects many have attributed to them: because of their vulnerability to electronic warfare and air-defense systems, they are unlikely to shift the

[17] For a discussion of how technological change is affecting the economy, society and politics, see for example Erik Brynjolfsson and Andrew McAfee, *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies* (New York, NY: W. W. Norton & Company, 2014); Klaus Schwab, *The Fourth Industrial Revolution* (New York, NY: Crown Business, 2016).

[18] Stephen Biddle, *Military Power: Explaining Victory and Defeat in Modern Battle* (Princeton, NJ: Princeton University Press, 2004), p. ix.

[19] Our understanding of the hider-seeker competition in the air domain is inspired by the dynamics in submarine warfare as explained by Owen R. Coté Jr., *The Third Battle: Innovation in the U.S. Navy's Silent Cold War Struggle with Soviet Submarines* (Newport, R.I.: Naval War College, 2009), p. 48; and Bryan Clark, *The Emerging Era in Undersea Warfare* (Washington, DC: Center for Strategy and Budgetary Assessment, 2015), p. 2. For a discussion of this competition, see for example Frank Heilenday, *Principles of Air Defense and Air Vehicle Penetration* (Washington, DC: CEEPress Books, 1988).

[20] James Brungess, *Setting the Context: Suppression of Enemy Air Defenses and Joint War Fighting in an Uncertain World* (Maxwell AFB: Air University Press, 1994); John A. Tirpak, "Dealing with Air Defense," *Air Force Magazine* (November 1999), pp. 25-29; and Carlo Kopp, "Evolving Technological Strategy in Advanced Air Defense Systems," *Joint Force Quarterly* No. 57 (Spring 2010), pp. 86-93.

offense-defense balance towards the offense; because of the support they require from other military assets, UAVs are unlikely to level the playing field; and because of the opportunities for concealment offered by terrain, electro-magnetic warfare, tactics and mission planning, drones are unlikely to cancel close combat and to erase the importance of skills and proficiency in modern warfare.

Despite its popularity, the drone revolution thesis, to our knowledge, has never been tested systematically, as its proponents have mostly relied on anecdotal or fragmented evidence.[21] For this reason, we test our hypotheses against the postulates of the drone revolution on three recent conflicts which saw extensive employment of drones: the Second Libyan War (2019-2020), the War in Syria (2011-2021), and the "43 Days War" in Nagorno-Karabakh (2020).[22] Methodologically, these cases are also particularly appropriate because they display significant within-case variation in key independent variables – such as availability of anti-air defense systems and electronic warfare systems as well as skills and combat proficiency – which, in turn, strengthen the confidence of our results. Despite being hailed as paradigmatic cases of the ensuing drone revolution in military affairs, these cases do not support the dominant narrative.

Our findings confirm the ongoing validity of the modern system of force employment also outside of its original application domain – land warfare. This is particularly remarkable given that air warfare is much more technology-intensive than land warfare, and given that more than 20 years have gone by since Biddle advanced his argument – during which, technological progress has advanced at an accelerating rate. Second, our analysis suggests also that policymakers should resist calls for radical changes in force structure and defense posture. The hype around drones as well as

[21] An exception is Heiko Borchert, Torben Schütz and Joseph Verbovszky, *Beware the Hype: What Military Conflicts in Ukraine, Syria, Libya, and Nagorno-Karabakh (Don't) Tell Us About the Future of War* (Hamburg, Germany: Defense AI Observatory, 2021).

[22] Each of the drones in *The Drone Databook* are assigned a classification ranging from I to III based largely on their maximum take-off weight: Class I (less than 150 kilograms), Class II (150 to 600 kilograms), and Class III (more than 600 kilograms). These classifications are drawn from NATO Standardization Agreement 4670—NATO's guidance for training drone operators. In this paper we focus on Class III. See Dan Gettinger, "The Drone Databook", The Center for the Study of the Drone at Bard College, October 2019, p. v, https://dronecenter.bard.edu/files/2019/10/CSD-Drone-Databook-Web.pdf.

around other so-called emerging and disruptive technologies needs to be tempered by a more careful assessment. As our assessment shows, the revolutionary effects of drones is more apparent than real.[23] Third, our analysis highlights the importance of factors that are often neglected in the public and political debate surrounding drones, such as skilled and proficient personnel as well as electronic warfare and air defense systems. As Kenneth Werrell notes with regard to the latter, "[r[eaders are more interested in the aircraft than the weapons that bring them down."[24] With our articles, we aim at correcting this imbalance of attention for a technology that has played an undisputed and significant role in the past 80 years.[25] Last but not least, our focus on air defense systems provides policy makers in regional powers and great powers with an important takeaway: providing local allies, as Turkey and Russia did, with air defense systems and electronic warfare systems (as well as skilled personnel employing them) is an effective and efficient way to rebalance an ongoing conflict, in which drones are extensively.

The rest of the article is organized as follows. In the first section, we summarize the main problem of the literature on drones and we show that even the skeptics have paid only limited attention to air defenses, if any at all. In the second section, we provide a conceptual framework to understand air operations. In the subsequent sections, we investigate the employment of drones in three recent conflicts: Syria, Libya, and Nagorno-Karabakh. Conclusions follow.

LITERATURE REVIEW

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[23] Some NATO countries, such as Poland and Latvia, for example have bought Turkish drones out of their alleged effectiveness against Russian air defense systems in recent conflicts. See "Is Latvia the Next NATO Nation to Order Bayraktar TB2 Drones?," *Defense World* (June 7, 2021), https://www.defenseworld.net/news/29744/Is_Latvia_the_Next_NATO_Nation_to_Order_Bayraktar_TB2_Drones_#.YNw7zhMzYmI.

[24] Kenneth P. Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense* (Maxwell AFB, AL: Air University Press, 2005), p. xix.

[25] According to some, radar "won" the Second War II. See for example Robert Buderi, *The Invention that Changed the World: How A Small Group of Radar Pioneers Won the Second World War and Launched a Technical Revolution* (New York, NY: Touchstone, 1996), p. 15. While this specific claim has been contested, the importance of radar is unquestioned. See Tony Devereux, *Messenger Gods of Battle: History of Electronic Warfare* (London, UK: Brassey's, 1991), pp. xvi-xvii. For the specific contribution that the "centimetric" radar played in defeating Nazi submarines in the Battle of the Atlantic, see for example Charles M. Sternhell and Alan M. Thorndike, *Antisubmarine Warfare in World War II*, OEG Report 51 (Washington, D.C.: Operations Evaluation Group, Office of the Chief of Naval Operations, 1946), pp 44-64.

Over the two decades, analysts, practitioners as well as scholars from of different epistemological, methodological and ontological traditions have paid increasing attention to robotics and in particular to the use of unmanned aerial vehicles in military operations.[26] Yet, rather than investigating their tactical and operational consequences, most of the literature has assumed them away in order to speculate about their strategic, political and metaphysical effects.[27] To a certain extent, this criticism applies both to drone enthusiasts and to skeptics.

Drone Revolution proponents

According to existing understandings, drones represent a major turning point in warfare.[28] James Rogers, for instance, argues that drones, like gunpowder, have been the most significant development in the history of weaponry.[29] Similarly, Tim Hsia and Jared Sperli believe that robotics will be the first revolution "in military affairs of the 21st century."[30] Scholars subscribing to this narrative, have identified three main features that, in their view, will enable drones to exert revolutionary effects on warfare and international politics.

First, allegedly, drones can overcome modern air defenses, a feature that yield an offensive advantage.[31] For instance, the Law Schools of Stanford and NYU implicitly reach this conclusion when suggesting that, with the diffusion of drone technology, "the risk of US-style practices of

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[27] Works that have studied the effects of drones in counter-insurgency operations represent an exception to this problem. See for example Benjamin Lambeth, *Air Operations in Israel's War against Hezbollah. Learning from Lebanon and Getting It Right in Gaza* (Santa Monica: RAND Corporation, 2011); Jenna Jordan, "The Effectiveness of the Drone Campaign against Al Qaeda Central: A Case Study." *Journal of Strategic Studies* 37, No. 1 (2014): 4–29; Patrick B. Johnston and Anoop K. Sarbahi, "The Impact of U.S. Drone Strikes on Terrorism in Pakistan," *International Studies Quarterly*, Vol. 60, No. 2 (June 2016), pp. 203–219; Michael Kreuzer, *Drones and the Future of Air Warfare. The Evolution of Remotely Piloted Aircraft* (Abingdon, UK: Routledge, 2017); Asfandyar Mir, "What Explains Counterterrorism Effectiveness? Evidence from the U.S. Drone War in Pakistan," *International Security* Vol. 43 No. 2 (2018): 45–83; Asfandyar Mir and Dylan Moore, "Drones, Surveillance, and Violence: Evidence and Theory from a U.S. Drone Program," University of Chicago, 2018.

[28] Cocker

[29] James Rogers, "What Has Been the Most Significant Development in The History of Weaponry?", *BBC History Magazine* (October 2020), p. 41.

[30] Tim Hsia and Jared Sperli, "How Cyberwarfare and Drones Have Revolutionized Warfare", *The New York Times, At War* (June 17, 2013) https://atwar.blogs.nytimes.com/author/tim-hsia-and-jared-sperli/.

[31] Michael Mayer, "The New Killer Drones: Understanding the Dtrategic Implications of Next-Generation Unmanned Combat Aerial Vehicles," *International Affairs* Vol. 91 No. 4 (2015): 774; Rogers, "What Has Been the Most Significant Development in The History Of Weaponry?," p. 41.

cross-border targeted killing spreading are clear."[32] Others have been more explicit and have highlighted that because of their small size, slow speed and low altitude, UAVs are more difficult to detect for modern air defense systems than traditional combat aircraft.[33] In this regard, for instance, Sarah Kreps and Sarah Maxey warn that "the offensive value of drones such as [the Reaper] is that they are almost impervious to traditional sensor systems such as joint surveillance target attack radar system (JSTARS) that are typically oriented toward larger assets."[34]

Second, because of UAV's allegedly cheap and dual-use components, many argue that drones lower the entry barriers for the acquisition, development and employment of advanced military capabilities, thus leveling the playing field among major powers and minor military actors.[35] More specifically, according to this view, drones are severing the century-old link between economic (and industrial) might and military power, allowing weaker and poorer actors to field state-of-the-art capabilities. In other words, drones are becoming the "poor man's air force."[36] The potential implications are transformative: "all armed forces in the world will use UAVs" and "every country on earth will be able to build or acquire drones capable of firing missiles within the next ten years."[37]

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[32] James Cavallaro, *Living Under Drones: Death, Injury and Trauma to Civilians from US Drone Practices in Pakistan*, International Human Rights and Conflict Resolution Clinic, Stanford Law School, New York University School of Law (NYUSoL), Global Justice Clinic, 2012, 140–41.

[33] Micheal J. Boyle, *The Drone Age: How Drone Technology Will Change War and Peace* (Oxford: Oxford University Press), pp. 152 and 167; John Parachini and Peter A. Wilson, "Drone-Era Warfare Shows the Operational Limits of Air Defense Systems," *Real Clear Defense* (July 2, 2020); Edward Guelfi, Buddhika Jayamaha, and Travis Robison, "The Imperative for the U.S. Military to Develop a Counter-UAS Strategy," *Joint Force Quarterly* Vol. 97 (2nd Quarter, 2020); D.B. Des Roches, "The Siren Song of the Drone: Understanding the Factors Driving GCC Drone Acquisition," *Al Jaazera Centre for Studies* (May 1, 2021).

[34] Sarah Kreps and Sarah Maxey, "Context Matters: The Transformative Nature of Drones on the Battlefield," in Giampiero Giacomello, Francesco N. Moro and Marco Valigi (eds.) *Technology and International Relations* (Cheltenham, UK: Edward Elgar Publishing), p. 80.

[35] Keith Hayward, "Unmanned Aerial Vehicles: A New Industrial System," *Royal Aeronautical Society* (November 2013); Anna H. Jackman, "Consumer Drone Evolutions: Trends, Spaces, Temporalities, Threats," *Defense & Security Analysis* Vol. 35, N. 4 (October 2019), 362-383; and Kerri Chávez and Ori Swed, "The Proliferation of Drones to Violent Nonstate Actors," *Defence Studies* (November 2020), pp. 1-24.

[36] See for example Nick Waters, "The Poor Man's Air Force? Rebel Drones Attack Russia's Airbase in Syria," *Bellingcat* (January 12, 2018), https://www.bellingcat.com/news/mena/2018/01/12/the_poor_mans_airforce/.

[37] See respectively, Ulrike E. Franke, "Military Robots and Drones," in *Routledge Handbook of Defence Studies*, edited by Galbreath, D. J. and J. R. Deni (London, UK: Routledge, 2018), p. 341; and Peter Tucker, "Every Country Will Have Armed Drones Within 10 Years," *Defense One* (May 6, 2014).

Third, drones have also allegedly made close combat obsolete. Since they enable long-range precision-strike, UAVs would permit countries to fight from distance without deploying troops on the ground.[38] In this regard, some claim that drones have eradicated "distance" in the modern battlefield, thus overcoming both psychological and moral obstacles to killing as well as barriers to unlimited projection of power around the globe.[39] Andrew Mumford, for instance, suggests that "developments in communications and information technology have the potential to nullify the twentieth-century belief in 'boots on the ground' as a proxy-war necessity."[40] As a result, Ian Shaw notes, "an army of robots can entrench US power without humans on the ground."[41] This perspective has received a additional support after the 2020 war in Nagorno-Karabakh between Armenia and Azerbaijan, which led many to even conclude that, because of drones, we are observing the "demise of the tank."[42]

These concerns explain to a significant extent why, over the past decade, a lot of attention has been placed on the diffusion of drones as well as on mechanism to control the spread and the employment of this technology.[43]

Skeptics of the Drone Revolution

Some works have questioned the consensus on the drone revolution. These works have significantly enhanced our understanding of the capabilities and limitations of current-generation drones. For example, some have pointed out that, like in any instance of technological transformation, drones call for additional complementary support, primarily in terms of command, control and communications infrastructure, which in turn limit their systematic use in military

[38] Shaw, "Predator Empire;" and Fukuyama, "Droning On in the Middle East."
[39] Derek Gregory, "From a View to a Kill: Drones and Late Modern War," *Theory, Culture & Society* Vol. 28 No. 7 (Winter 2012), pp.188-215; and Ian G.R. Shaw, "Robot Wars: US Empire and Geopolitics in the Robotic Age," *Security Dialogue* Vol. 48, No. 5 (October 2017), pp. 451-470.
[40] Andrew Mumford, "Proxy Warfare and the Future of Conflict." *RUSI Journal* Vol. 158, No. 2 (2013): 43.
[41] Shaw, "Predator Empire," 458.
[42] "The Azerbaijan-Armenia conflict hints at the future of war," *The Economist* (October 10, 2020), https://www.economist.com/europe/2020/10/08/the-azerbaijan-armenia-conflict-hints-at-the-future-of-war.
[43] Micah Zenko and Sarah Kreps, "Limiting Armed Drone Proliferation," *Council Special Report* no. 69, Council on Foreign Relations, Center for Preventive Action, Washington, DC, June 2014.

operation to only wealthy and military powerful countries.[44] Others, along the same lines, have highlighted that current-generation drones are vulnerable to modern air defense systems, which in turn makes them unlikely candidate for conventional conflicts against militarily capable countries.[45] Yet, this literature has not address all issues and questions.

First, these works have not systematically investigated, at the empirical level, the employment of drones in modern military operations. Thus, for instance, some key claims, such as drones' vulnerability to modern air defense systems, have not been verified. This is particularly important not only because drone revolution proponents advance the opposite proposition but also because some skeptics have switched position on this issue.[46] Similarly, some skeptics have changed position on drones' infrastructural requirements, thus raising questions on the empirical accuracy of this claim.[47] Additionally, in recent conflicts such as in Libya and Nagorno-Karabakh, current-generation drones were successfully employed in conventional setting, also against enemy air defense systems, thus making an empirical investigation particularly pressing. Finally, scholars who have noted the vulnerability of current-generation drones to modern air defense systems have considered drones in isolation, and not as part of an existing force structure and have paid insufficient attention to variations in skill and capabilities in air defense systems.[48]

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[44] See for example Shashank Joshi and Aaron Stein, "Emerging Drone Nations," *Survival* Vol. 55, no. 5 (October-November 2013), pp. 53-78; Austin Long, "Dueling Asymmetries: International Terrorism, Insurgency and Drone Warfare in the 21st Century," in *The Future of Warfare in the 21st Century* (Abu Dhabi: Emirates Center for Strategic Studies and Research, 2014), pp. 13-36: and Andrea Gilli and Mauro Gilli, "The Diffusion of Drone Warfare? Industrial, Organizational, and Infrastructural Constraints," *Security Studies* Vol. 25, No. 1 (Spring 2016), pp. 50-84.

[45] See for example Gilli and Gilli, "The Diffusion of Drone Warfare?," p. 80; and Michael C. Horowitz, Sarah E. Kreps and Matthew Fuhrmann, "Separating Fact from Fiction in the Debate over Drone Proliferation," *International Security* Vol. 41, No. 2 (Fall 2016), pp. 7-42.

[46] See for example Kreps and Sarah Maxey, "Context Matters," p. 80; and Horowitz, Kreps and Fuhrmann, "Separating Fact from Fiction in the Debate over Drone Proliferation," p. 16.

[47] See for example John Kaag and Sarah Kreps, *Drone Warfare* (Hoboken, N.J.: Wiley & Co., 2014), p. 148; and Micah Zenko and Sarah Kreps, "Limiting Armed Drone Proliferation," *Council Special Report* no. 69, Council on Foreign Relations, Center for Preventive Action, Washington, DC, June 2014, p. x

[48] One significant exception in this regard is a report by the Defense Artificial Intelligence Observatory on the employment of drones in recent conflicts, which has warned analysts, observers and policy-makers to "beware of the hype" surrounding this technology. While this work has stressed the need to consider the role of air defense systems, electronic warfare, and supporting assets, it has not provided a framework that permits to put emerging technologies in the context of the modern battlefield to assess their role. This is what we do in this article. See Borchert, Schütz and Verbovszky, *Beware the Hype.*

The Modern System of Force Employment in Air Warfare

In order to address the problems of the existing literature on drone warfare, we advance a theory of military effectiveness in air operations. In this section, we adopt and adapt Stephen Biddle's modern system of force employment to the realm of air warfare.[49]

From the First to the Second Firepower Revolution

The starting point of Biddle's analysis is the firepower revolution that took place shortly before World War I.[50] This firepower revolution was the product of a set of technological changes in guns manufacturing that dramatically increased the rate, volume and precision of fire.[51] As a result of this revolution, exposure to "radical firepower" became lethal, and troops had thus to devise new solutions to advance on the battlefield. These solutions are what Biddle calls the modern system of force employment, a set of tactics and procedures entailing "cover, concealment, dispersion, suppression, small-unit independent maneuver and combined arms at the tactical level" as well as "depth, reserves and differential concentration at the operational level of war."[52] These techniques, Biddle contends, "sharply reduce vulnerability to even twenty-first century weapons and sensors."[53] Evidence shows that to understand the outcome of modern battles, we need to look at which side has mastered the modern system.[54]

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[49] Biddle, *Military Power.*
[50] Biddle, *Military Power*, p. 3
[51] Biddle, *Military Power*, p. 3. For a discussion of the firepower revolution, see for example John Ellis, *The Social History of the Machine Gun* (Baltimore, MD: The Johns Hopkins University Press, 1975), pp. 79-109 and 111-148; Daniel R. Headrick, *The Tools of Empire: Technology and European Imperialism in Nineteenth Century* (New York, Oxford University Press, 1981), pp. 83-126.
[52] Biddle, *Military Power*, p.3 and 28.
[53] Biddle, *Military Power*, p.3.
[54] Among the others, see for example his Stephen D. Biddle and Robert Zirkle, "Technology, Civil-Military Relations, and Warfare in the Developing World," *Journal of Strategic Studies*, Vol. 19, No. 2 (June 1996), pp. 171–212; Stephen Biddle, "The Past as Prologue: Assessing theories of future warfare," *Security Studies* Vol. 8, No. 1 (1998), pp. 1-74; Stephen D. Biddle, *Afghanistan and the Future of Warfare: Implications for Army and Defense Policy* (Carlisle, Pa.: Strategic

We maintain that starting from the 1960s, concomitant developments in electronics, materials and propulsion, among others, brought about a second firepower revolution that has dramatically increasing the lethality of air warfare, for air penetration as well as for air defense.[55] This second firepower revolution is part of what the late General William DePuy called the era of "new lethality" in which "what we see we can hit; what we hit we can kill."[56] Such revolution, we claim, stemmed from significant improvements in detection, communication, precision and destruction.[57] These improvements, in turn, have led a hider-seeker competition between air forces and air defenses, which entails hiding from enemy sensors, while seeking enemy targets.[58]

The Modern System of Force Employment

This hider-seeker competition rewards those who master the employment of tactics, techniques, procedures, technologies, and capabilities aimed at limiting exposure to enemy fire while successfully detecting and targeting the enemy – i.e., the modern system of force employment –,

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Studies Institute, U.S. Army War College, 2002); Stephen D. Biddle, and Stephen Long, "Democracy and Military Effectiveness: A Deeper Look." *Journal of Conflict Resolution* 48, no. 4 (August 2004): 525–46; Stephen D. Biddle, "Speed kills? Reassessing the Role of Speed, Precision, and Situation Awareness in the Fall of Saddam," *Journal of Strategic Studies*, Vol. 30, No. 1 (2007), pp. 3-46.

55 Among the most extensive and detailed treatments of this topic are Lon O. Nordeen, *Air Warfare in the Missile Age* (Washington, DC: The Smithsonian Institution Press, 1965); Michael Russell Rip and James M. Hasik, *The Precision Revolution: GPS and the Future of Aerial Warfare* (Annapolis, MD: Naval Institute Press, 2002); and Barry D. Watts, *Six Decades of Guided Munitions and Battle Networks: Progress and Prospects* (Washington, DC: Center for Strategic and Budgetary Assessment, 2007); and Norman Friedman, *Network-Centric Warfare: How Navies Learned to Fight Smarter Through Three World Wars* (Annapolis, MD: Naval Institute Press, 2009).

56 Dwight E. Phillips Jr., *Reengineering Institutional Culture and the American Way of War in the Post-Vietnam U.S. Army, 1968–1989* (University of Chicago, 2014), p. 59, cited in Stephen Johnson, *The Blind Strategist: John Boyd and the American Art of War* (Dunedin, New Zealand: Exisle Publishing, 2021), p. 26.

57 The first sign of this transformation was the shooting down of the U2 *Lady Hawk* in 1960 by the Soviet S-75 Dvina (NATO reporting name SA-2 Guideline), which made high-altitude flight no longer sufficient to defeat enemy air defenses. The subsequent employment of Soviet surface-to-air missiles in Vietnam (with the shooting downs of American premier long-range strategic Bomber, the B-52 *Stratofortress*) and then in the Middle East, further confirmed the beginning of the new era in air warfare, as testified by the fact that Israel lost 50 aircraft in the first 5 days of the Yom Kippur War (1973). See Cordesman and Wagner, *The Lessons of Modern War – Volume I*, pp. xx; Brungess, *Setting the Context*, pp. xx; and Kopp, "Evolving Technological Strategy in Advanced Air Defense Systems."

58 For a discussion of this competition, see for example Heilenday, *Principles of Air Defense and Air Vehicle Penetration*, pp. 9.1-9.20. For a discussion of this transformation, see for example Richard P. McMullen, "History of Air Defense Weapons, 1946–1962," *Air Defense Command Historical Study Number 14* (Historical Division, Office of Information, HQ Air Defense Command, 1963), pp. xx; Zaloga, *Soviet Air Defense*, pp. xx; Kenneth Schaffel, *The Emerging Shield The Air Force and the Evolution of Continental Air Defense 1945-1960* (Washington, D.C.: Office of Air Force History, 1991), pp. xx; Brungess, *Setting the Context*, pp. xx; Kenneth P. Werrell, *Archie to SAM*, pp. xx.

and it punishes severely those who fail at it. In comparison to land warfare, the modern system of force employment is much more challenging in air warfare.

For air defenses, the modern system of force employment entails many of the measures and procedures that ground forces have to master, with some key differences.[59] First opportunities for cover are much more limited for air defenses, since they have to hide from aircraft trying to destroy them, and the difference in elevation between the two deprive the former of the opportunities for cover provided by irregularities in the terrain – while trenches and gullies shield troops on the ground from ground-level firepower, they lose most of their effectiveness against air-to-ground weapons. Second, concealment is inherently much more difficult for air defense than for ground troops tasked with defending a given territory, since the former needs to actively search for incoming aerial intruders, which requires the employment of radar, whose electro-magnetic emissions inevitably give up the position of the radar outpost.[60] Moreover, also when switched off, air defense systems are still difficult to conceal as airborne-sensors can capture radio communications, as well as the thermal, radar or visual signature of air defenses (produced by power-generation, radar reflections or poor camouflaging).[61] Here, the complexity of the surrounding terrain becomes central, as some environments, such as the desert, provide much less opportunity for concealment than others, such as wood and forests.[62] Last but not least, in comparison to land warfare, air defense requires advanced technology for detecting, identifying,

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[59] Air defense can be divided in passive and active measures. Passive air defense include camouflage, concealment, deception, dispersion, reconstitution, redundancy, detection and warning systems, and the use of protective construction. Active air defense includes air defense weapons, electronic warfare, and other available weapons. For a general discussion, see for example *Techniques for Combined Arms for Air Defense – Field Manual ATP 3-01.8* (Washington, DC: Headquarters Department of the Army, 2016), pp. 3.1-4.7.
[60] Radar provides all-weather, night-and-day, very long-range detection. However, its emission of electro-magnetic signals (in the microwave and radiowave frequency of the electro-magnetic spectrum) can be detected by enemy radar warning receivers and anti-radiation missiles. See *Electronic Warfare Fundamentals*, pp. 1.2-1.6; and Simon Kingsley and Shaun Quegan, *Understanding Radar Systems* (Norwich, NY: SciTech Publishing, 1999), pp. 1-47.
[61] See *Techniques for Combined Arms for Air Defense*, pp. 3.1-3.6.
[62] As Cordesman and Wagner have put it, "[i]t is simply very difficult to hide in the open desert…. While the openness of desert terrain typically provides the necessary mobility for armored movements, it facilitates vulnerability to air power." Anthony H. Cordesman and Abraham R. Wagner, *The Lessons of Modern War – Volume I: The Arab-Israeli Conflicts 1973-1989* (Oxford, UK: Westview Press, 1990), p. 38.

tracking and engaging enemy intruders.[63] While in land warfare, very well-trained soldiers armed with automatic guns and explosives can pose a serious threat to a very advanced armies, in air defense, much more advanced technological capabilities are required.[64]

For penetrating aircraft, the modern system of force employment is even more daunting than for air defense. First of all, the air domain, essentially, does not offer opportunities for cover from enemy fire, which means that once detected an aircraft has to rely only on its own capabilities for avoiding interception.[65] This aspect is particularly important because aircraft can tolerate very little structural damage, and therefore they need to avoid detection altogether.[66] Moreover, the air domain offers also only limited opportunities for concealment, in contrast to the land domain.[67] This problem is exacerbated by the fact that to radar systems, aircraft are significantly different from their background they operate in, the sky.[68] This means that, everything else being equal, in

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63 These are, obviously, radars operating at different frequencies (hence ranges), command and control centers, different engagement systems for low-altitude and high-altitude targets, electronic counter-countermeasures, and much more.

64 For a discussion of land warfare, see for example Biddle, *Afghanistan and the Future of Warfare.* For air defense, see *Electronic Warfare Fundamentals.*

65 The only real exception is for rotary-wings aircraft that can move vertically to take advantage of natural or artificial obstacles as shields against enemy fire. See for example *Techniques for Combined Arms for Air Defense*, pp. 1.6-1.7. Also fixed-wing aircraft can take advantage of natural and artificial obstacles, but as we explain later, more for concealment than for cover. With regard to the capabilities to avoid interception once detected, these are, for example, the capacity to outmaneuver an incoming missile (which depends on the acceleration and maneuverability of an aircraft) and on passive defensive systems such as chaff or flares that deceive guided munitions. See *Electronic Warfare Fundamentals*, pp. 13.1-13.16 and 15.1-15.8.

66 See Stillion and Clark, *What It Takes to Win: Succeeding in 21st Century Battle Network Competitions* (Washington, DC: Center for Strategic and Budgetary Assessment, 2015), p. 48. For space reason, we cannot discuss in detail the different types of damage air defense systems can inflict on an aircraft. What is important is that damage to many critical parts of an aircraft, including the engine, the wings, the external sensors, the instrument panel and commands, cables and electro-hydraulic transmissions, and of course the pilot can be sufficient to force an aircraft to abort the mission or to emergency land – to which one must add lethal damage that lead the aircraft to crash to the ground or to explode mid-air. For a discussion, see for example Matthew C. Waddell, *Surface-To-Air Guided Missile. Systems Methods of Tactical Analysis* (Silver Spring, MD: Johns Hopkins University – Physics Applied Laboratory, 1961), pp. 21-23.

67 There are, of course, opportunities for concealment, such as taking advantage of the super-refracting duct that forms, under certain conditions, over large bodies of water and that shields aircraft flying above a given altitude from radar detection or flying at very low-altitude to postpone detection by ground based radar (hence the metaphor "flying under the radar") – a because of the curvature of the earth, radar beams, which travel in a straight "line-of-sight", will not be able to illuminate objects at long range that fly below a given altitude, this area is known as "radar shadow." See *Electronic Warfare Fundamentals*, pp. 2.9-2.14; and Bronk, "Modern Russian and Chinese Integrated Air Defence Systems," p. 10.

68 Significantly, here, is intended in statistical terms. Detection is a probabilistic assessment that relies on inferential statistics in order to distinguish an object from its background, and to minimize the risk of a false alarm (false positive) and of a miss (false negative). Since sensors (visual, thermal sensors, and electro-magnetic) receive aggregate information that contains either only ambient noise when the target is not present; or ambient noise and the signal generated by the target when the target is present, detection requires disentangling signal from the noise (for simplicity we use the term noise, even though we are referring to clutter – i.e., the unwanted return originating from airborne and ground scatterers different from the intruders). The logic behind signal processing is the same to which social

the hider-seeker competition, penetrating aircraft are much easier to detect and target than land-based anti-air defense systems, because of the differences of the surrounding environment – simple for aircraft, and complex for ground-based systems.[69] Finally, air penetration depends massively on technology for limiting exposure to enemy fire power. In the next two sections, we explain the hider-seeker competition between air defense and air penetration more in detail.

The Modern System for Air Penetration

Modern air defense systems represent a lethal threat for military aircraft.[70] Accordingly, military aircraft have to avoid, degrade or destroy ground-based air defense systems in order to penetrate the enemy's air space and carry out the intended mission.[71] This challenge varies in intensity depending on how advanced the enemy's air defenses are – i.e., the capabilities and sophistication of the available technologies and assets as well as the skill and proficiency of personnel operating them.

A country that does not possess long-range high-altitude anti-air defense system will be able to pose a challenge only to slow and low-flying aircraft – through anti-air artillery and man-portable air defense systems (MANPADs).[72] In this case, air penetration will still require significant

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sciences are accustomed with regard to hypothesis testing. For a general introduction to detection, inferential statistics and signal processing, see for example Mark Denny, *Blip, Ping & Buzz: Making Sense of Radar and Sonar* (Baltimore, MD: The Johns Hopkins University Press, 2008), pp. 46-89; and J.C Toomay and Paul J. Hannen, *Radar Principles for the Non-Specialist* (Raleigh, NC: SciTech Publishing, 2004), pp. 1-44. For an analogy between inferential statistics and signal processing, see Alan V. Oppenheim and George C. Verghese, *Signals, Systems, And Inference — Class Notes for 6.011: Introduction to Communication, Control and Signal Processing Spring 2010*, chapter 13, available at https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-011-introduction-to-communication-control-and-signal-processing-spring-2010/readings/MIT6_011S10_chap13.pdf.

69 Stephen Biddle and Ivan Oelrich, "Future Warfare in the Western Pacific: Chinese Antiaccess/Area Denial, U.S. AirSea Battle, and Command of the Commons in East Asia," *International Security*, vol. 41. no. 1. (Summer 2016), pp. 12-13.

70 For a discussion of air defense, see for example Steven J. Zaloga, *Soviet Air Defence Missiles: Design, Development and Tactics* (London, UK: Jane's Information Group, 1989); *Electronic Warfare Fundamentals* (Nellis AFB, NV: Air Combat Command Training Support Squadron, 2000), pp. 1.6-1.10; Maj. Peter W. Mattes, USAF, "Systems of Systems: What, Exactly, is an Integrated Air Defense System?" *The Mitchell Forum* No 26 (June 2019); Justin Bronk, "Modern Russian and Chinese Integrated Air Defence Systems: The Nature of the Threat, Growth Trajectory and Western Options," *RUSI Occasional Paper* (January 2020).

71 Heilenday, *Principles of Air Defense and Air Vehicle Penetration*, pp. 2.1-2.6.

72 The most known MANPADS are the American FIM-92 *Stinger*, the 9k32 *Strela*-2 (NATO reporting name: SA-7 Grail), and the 9M336 *Verba* (NATO reporting name: SA). They depend on an infra-red sensor that tracks heat emissions like engine exhaust, which in turn explains the limited range and altitude reach of these systems. See for example "US Army starts upgrade of FIM-92E Stinger Block I missiles," *Army Technology* 2 November 2014; "New

infrastructural support in terms of intelligence gathering and processing, target acquisition, mission planning as well as communication and control.[73] However, penetrating such a permissive environment will not pose substantial challenges: flying at high altitude will be sufficient to avoid enemy firepower, and therefore degrading and destroying enemy air defenses will not be necessary.[74]

The challenge of air penetration becomes dramatically more serious as the enemy's air defense systems become more advanced.[75] Against a country that possesses an advanced integrated air defense systems, air penetration will require the coordinated employment of a set of tactics, procedures, techniques, technologies, operational planning and supporting assets and capabilities – i.e., intelligence gathering, mission planning, dedicated flight route, decoys, suppression of enemy air defense systems (SEAD), electronic warfare (EW), electronic support (ES), target acquisition (TA), and fusion of multiple sources of intelligence, among others.[76] These, in turn, call not only for experienced, proficient and skilled personnel, but also for advanced technological capabilities as well as for tight integration and coordination of many different assets to be employed in strict and time-sensitive sequence, with very limited margins for error, so as to maximize surprise and hence impact, and minimize the threats to the aircraft, and hence potential losses.[77]

Intelligence, surveillance and reconnaissance platforms must detect and locate the enemy's air defense systems and share exact coordinates in a timely manner with mission planners as well as with assets tasked with SEAD and EW, so that they can respectively identify a path profile that

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Russian Air Defense System Gibka-S Works against Ultra-low Flying Threats," *Defense World* (December 26, 2019); GlobalSecurity.org, "9M336 Verba (Willow)," https://www.globalsecurity.org/military/world/ russia/9m336.htm

[73] Joshi and Stein, "Emerging Drone Nations;" and Gilli and Gilli, "The Diffusion of Drone Warfare?".

[74] [nota corretta su flying in in permissive environment]

[75] In addition to the actual cost imposed by air defense on enemy intruders, there is also a psychological effect (or virtual attrition) in that it forces the enemy to change its mission. For instance, the threat of surface-to-air missiles during the Vietnam War forced U.S. aircraft at flying below a given altitude, thus exposing them to the threat of anti-air artillery. Sie Werrell, pp.

[76] *Electronic Warfare Fundamentals*, pp. 17.15-17.20. For a more general discussion, see Chris Dougherty, "Moving Beyond A2/AD," *CNAS* (December 3, 2020).

[77] For an empirical discussion, see for example the survey of the 1991 Gulf War in Eliot A. Cohen, *Gulf War Air Power Survey Vol. II: Operations and Effects and Effectiveness* (Washington, D.C.: Office of the Secretary of the Air Force, 1993), pp. 115-158. For a general of several key cases, see Brungess, *Setting the Context*, pp. 1-50.

minimize the risk of detection as well as target and degraded enemy's outposts before they relocate.[78] Moreover, in order to address the threat posed by mobile or concealed air defense systems, air penetration requires the coordinated employment of decoys and suppression assets so that enemy's air defence systems switch on their radar and thus give up their position, which in turn allows SEAD aircraft to detect and target them.[79] Additionally, electronic warfare assets must effectively degrade (i.e., "blind"), from distance, remaining enemy radars, in coordination with penetrating strike aircraft so as to minimize the threats for the latter.[80] For this to be the case, strike aircraft must proceed through temporary narrow "corridors" resulting from degraded or destroyed enemy air defense systems, following a flight profile that takes advantage of natural and artificial

[78] This entails the collection and rapid processing of multiple type of data from of different of intelligence, including signal, electronic, photographic, human and operational. Against technological deficient or non-proficient enemy, these tasks will be easier to carry out, as the enemy will fail at hiding and concealing its air defenses. Against more capable enemies, these tasks will become more difficult. For a discussion of this aspect in the Israel-Syrian 1982 war, see Rebecca Grant, "The Bekaa Valley War," *Air Force Magazine* Vol. 85 (June 2002); Benjamin S. Lambeth, *Moscow's Lessons from the 1982 Lebanon Air War* (Santa Monica, CA: RAND Corporation, 1984), pp. 4-8; and David E. Clary, *Bekaa Valley – A Case Study* (Maxwell AFB, AL: Air Command and Staff College – Air University, 1988), pp. 9-11. For a general discussion on data fusion, see for example *David L. Hall and James Llinas* "Multisensor Data Fusion," Edited by Martin E. Liggins David L. Hall James Llinas (eds.), *Handbook of Multisensor Data Fusion: Theory and Practice – Second Edition* (Boca Ranton, FL: CRC Press, 2008), pp. 1-14.

[79] To be effective against capable enemies, decoys need to have a radar return similar to one's own attacking aircraft, which require specific technological capabilities. See discussion in David Clary, "EW in the Bekaa Valley: A New Look," *Journal of Electronic Defense* (June 1990), p 38; and in Tirpak, "Dealing with Air Defense," p. 28. Similarly, to be effective, anti-radiation missiles need to possess "high-speed" so that they can target a radar outpost before it relocates. Altogether, against a capable skilled enemy that possess sufficiently advanced capabilities, suppression of enemy air defense systems will pose significant challenges. During the Kosovo War of 1999, for instance, the neutralizing Serbian IADS was, according to the commander of NATO forces in Bosnia, "like digging out potatoes one at a time." See Benjamin S. Lambeth, "Kosovo and the Continuing SEAD Challenge," Vol. XVI, No. 2 (Summer 2002), p. 9. For a general discussion of the challenge posed by Yugoslavia, see Tirpak, "Dealing with Air Defense," p. 26; Barry R. Posen, "The War for Kosovo: Serbia's Political-Military Strategy," *International Security*, vol. 24. no. 4. (Spring 2000), pp. 39-84; Lambeth, "Kosovo and the Continuing SEAD Challenge;" and Rip and Hasik, *The Precision Revolution*, pp. 381-417.

[80] The employment of EW to degrade enemy's radar dates back to World War II. During the Vietnam War, it became more extensively employed in coordination with strike aircraft, as a response to North Vietnam employing Soviet radars in its integrated air defense network. Defeating the North Vietnam's radar through EW became so demanding that, at one point, for every strike aircraft, there was a six supporting specialized EW aircraft (EB-66). See Rip and Hasik, *The Precision Revolution*, pp. 19-34; and Marshall L. Michel III, *Clashes: Air Combat over North Vietnam 1965–1972* (Annapolis, MD: Naval Institute Press, 1997), pp. xx. For a general discussion, see Alfred Price, *War in the Fourth Dimension: U.S. Electronic Warfare, From the Vietnam War to the Present* (London, UK: Greenhill Books, 2001). During the Gulf War, the stealth aircraft employed, the F-117 *Nighthawk*, did not require the support of EW assets, as its small radar signature significantly reduced the range of detection, thus allowing it to penetrate Iraqi's air defense systems with impunity. However, advance in radar systems have largely degraded such advantage, so much so that the F-35 *Joint Strike Fighter Lightening II* possess its own electronic warfare suit as its stealth performance is considered no longer sufficient against modern air defense systems like the Russian S-400. See Cohen, *Gulf War Air Power Survey Vol. II: Operations and Effects and Effectiveness* (Washington, D.C.: Office of the Secretary of the Air Force, 1993), p. 123; Loren Thompson "The F-35 Isn't Just 'Stealthy': Here's How Its Electronic Warfare System Gives It an Edge," *Forbes* (May 13, 2019); and Kopp, "Evolving Technological Strategy in Advanced Air Defense Systems," pp. 89-92.

obstacles like mountains or buildings.[81] This is true for any penetrating aircraft, low observable included, given the lethality of modern air defense systems, as the shooting down of the F-117 Nighthawk in Yugoslavia shows.[82] Last but not least, penetrating aircraft requires reliable and secure communications.[83]

The Modern System for Air Defense

Air defense systems must detect, identify, track and, if needed, engage intruders, while avoiding being degraded by enemy's electronic countermeasures (jamming) or being targeted by enemy's suppression of enemy air defense assets.[84] The challenge of this tasks depend on the capabilities of the adversary – the aircraft and supporting assets (ISR, SEAD and EW) that the enemy possesses, mission planning capabilities and concepts of operations, the training and skills of pilots and other personnel, as well the proficiency in carrying out coordinated operations. Defending against a country that possesses only low-performing aircraft and no supporting asset, for instance, will require relatively limited effort, skills and capabilities –such as AAA and MANPADS. However, as the performance of the aircraft as well as the supporting assets increase, the challenge of air defense becomes more and more daunting – especially in light of the enemy's attempt to degrade (EW) and destroy (SEAD) one's own air defense outposts and systems. To accomplish this goal, air defense requires the employment of a set of tactics, procedures, techniques,

[81] For an extensive discussion of how mission planning, decoys, and EW can increase aircraft survivability in a contested airspace, see Rebecca Grant, *The Radar Game: Understanding Stealth and Aircraft Survivability* (Arlington, VA: Mitchell Institute Press, 2010), pp. 36-53. See also Maj Gen Mark Barrett, USAF (Ret.) with Col Mace Carpenter, USAF (Ret.), *Survivability in the Digital Age: The Imperative for Stealth* (Arlington, VA: The Mitchell Institute for Aerospace Studies Air Force Association, 2017), p. 30.

[82] Exact locations of enemy air defence outposts is important even for "low observable" (i.e., stealth) aircraft in that it permits to identify a path profile that further minimizes the risk of detection. See Myron Hura and Gary McLeod, *Route Planning Issues for Low Observable Aircraft and Cruise Missiles: Implications for the Intelligence Community* (Santa Monica, CA: RAND Corporation, 1993). On the shooting down of the F-117 in Yugoslavia, see for example Lambeth, "Kosovo and the Continuing SEAD Challenge," pp. 12-14.

[83] Jeff Hagen et al., *The Foundations of Operational Resilience— Assessing the Ability to Operate in an Anti-Access/Area Denial (A2/AD) Environment: The Analytical Framework, Lexicon, and Characteristics of the Operational Resilience Analysis Model (ORAM)* (Santa Monica, Calif.: RAND Corporation, 2016).

[84] Heilenday, *Principles of Air Defense and Air Vehicle Penetration*, pp. 1.1-1.5. Also in this case, the effectiveness of SEAD is not limited to the number of radar outposts that it destroys or disables, but also to psychological effect on enemy's air defenses (i.e., virtual attrition), forcing many ground-based radars to remain silent or to operate only intermittedly. See for example Brungess, *Setting the Context*, p. 6.

technologies, operational planning and supporting assets and capabilities that allow for the long-range detection, correct identification, exact localization, continuous tracking and successful engagement of intruders while avoiding exposing its own assets to detection, localization and destruction – this calls, among others, for early warning systems, command and control (C2) centers, secure communications, mobile air defense systems, electronic counter-counter-measures (ECCM), low-probability intercept (LPI) radar, as well as skilled and proficient personnel.

Air defense require first and foremost early warning systems that provide long-range detection, so as to maximize the time for other systems to acquire and engage the incoming target – generally, this is in the form of early warning radars, that need to be outside the reach of enemy's SEAD or EW (i.e., deep inside one's territory or in safe heavens).[85] Moreover, air defense requires a secure and reliable system of communication that pass information of an approaching intruder to command and control centers and in turn to multiple engagement outpost, so that they can acquire, track and engage the target.[86] Additionally, these engagement outposts need not only to possess radars endowed with advanced electronic counter-counter measures (such as frequency hopping and low-probability intercept) to avoid being jammed or detected, but also to rapidly relocate when needed in order to avoid being targeted, taking advantage of terrain for cover and concealment.[87] Last but not least, to maximize the chance of intercepting an incoming enemy aircraft, a country must possess multiple type of engagement systems, for both low-range/low-altitude (anti-air aircraft) as well as long-range/high-altitude targets (surface-to-air missiles).[88]

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[85] This is why, for example, North Vietnam, during the Vietnam War, positioned its Early Warning radars north of the 20th parallel where they could not be targeted, because of diplomatic/political reasons, by U.S. forces; and why Yugoslavia, during the 1999 war, positioned its early warning radars in Montenegro, a territory that NATO did not want to strike, again for diplomatic/political reasons. Yugoslavia also had "spotters" outside of Italy's Aviano air base, from where many U.S. aircraft were taking off. See respectively, Nordeen, *Air Warfare in the Missile Age*, p. 28; and Lambeth, "Kosovo and the Continuing SEAD Challenge," p. 13. For countries that can afford it, early warning radars are both ground-based and airborne-based, in that each strength compensates for the weakness of the other.
[86] Mattes, "Systems of Systems."
[87] On frequency hopping and low-probability intercept, see for example Kingsley and Quegan, *Understanding Radar Systems*, pp. 286-295. On anti-air defense mobility, see for example
[88] Surface-to-air missile provide long-range and high-altitude reach, making it prohibitive for any aircraft without any active (jamming) or passive (reduction in observability) measure to penetrate enemy air defences at high altitude. However, missiles have a minimum altitude below which they cannot engage targets due to clutter interference (generally about 1km). Short-range, low-altitude air defense systems provide defense against low-flying targets.

Altogether, performing all these tasks is very challenging. Detection, identification and tracking of incoming enemy aircraft compete with enemy deception (decoys) and civilian aircraft, with features and tactics of the enemy aimed at delaying or reducing the chance of detection (flying at very low altitude to take advantage of the "radar shadow" as well as of "ground clutter"), with EW degrading the performance of radar systems, and the threat of SEAD forcing radars to remain switched off and hide, while destroying those who do not.[89] Moreover, maintaining radio silence, enforcing emission control, and relocating mobile air defense systems is overall burdensome, dangerous and difficult – in particular where terrains offers little opportunities for concealment.[90] Similarly, electronic counter-counter measures are effective only as long as they are more advanced than the enemy's electronic counter-measures, and this requires taking part in this never-ending technological race.[91] Last but not least, air defense requires also very skilled and proficient personnel and appropriate concepts of operation, as both the capacity to detect, track and engage potential intruders as well as the skill in avoiding detection from enemy SEAD are strongly influenced by personnel.[92]

Research Design

In this section, we derive the observable implications of both the drone revolution thesis and of the modern system of force employment in air warfare. Then, we illustrate the case studies we

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[89] An integrated air defense system that relies on multiple airborne and ground-based sensors and shooters, including ground-based early warning radars and airborne early warning and control system (AEW&C), patrolling aircraft, mobile long-range and short-range anti-air defense system, advanced electronic counter-countermeasures, will have a high probability successfully addressing this threat. The integration of multiple sensors will compensate for the individual weaknesses of each. The availability of advanced signal processing with clutter suppression and of a large stock of environmental and enemy's data will lower the probability of false alarms and of missed detections, especially against aerial vehicles with a small radar signature. See for example William G. Ballard, "Fire-Control Radar," in William L. Melvin and James A. Scheer (eds.), *Principles of Modern Radar: Vol. III: Radar Applications* (Edison, NJ: SciTech Publishing, 2014), pp. 117-174; David J. Lynch, *Introduction to RF Stealth* (Raleigh, NC: SciTech Publishing, 2004), pp. 195-274; Oleg I. Sukharevsky, ed., *Electromagnetic Wave Scattering by Aerial and Ground Radar Objects* (Boca Raton, FL: CRC Press, 2014), p. xix.

[90] [cercare fonte corretta]

[91] Moreover, it needs advanced equipment, in terms not only of radar operating at different frequencies, signal processing, electronic counter-countermeasures, but also shooters for low- and Finally, it requires also

[92] Bruce R. Orvis, Michael Childress, and J. Michael Polich, *Effect of Personnel Quality on the Performance of Patriot Air Defense System Operators* (Santa Monica, CA: RAND Corporation, 1992).

have investigate and show why the within-variation they observe permit to increase the confidence in our results.

Drone revolution thesis: hypotheses.

From the existing consensus on the ensuing drone-driven revolution on military affairs, we can derive three simple expectations. First, since drones can, allegedly, overcome existing air defense systems, thus yielding an offensive advantage, we should find that drones experienced none-to-very limited attrition rate against both electronic warfare and air defense systems. Second, since drones are, according to this consensus, easy and cheap to develop, they should be, in relative terms, more available and used more extensively and effectively by weaker actors which, in turn, should also have been able to ramp-up drone production to offset their tactical inferiority or combat losses. Last, but not least, since drones enable long-range precision-strike, close combat and force employment should progressively lose salience in conflict.

Modern system of force employment: hypotheses.

From our application of the modern system of force employment to air warfare, we derive three directly opposite expectations.

First, since current-generation drones can be detected and engaged by integrated air defense, they do not have radar warning receivers and they lack passive and active self-defense measures against incoming fire (whether chaff, flares, or maneuverability), we hypothesize that drones will enjoy air impunity against adversaries lacking electronic warfare and air-defense systems and, in contrast, will experience high attrition rates against capable and competent adversaries. We also expect that adoption and non-adoption of techniques and procedures aimed at reducing the detectability of ground-based air defense systems will inversely correlate with enemy drones' performance. Precisely

H1: the offensive advantage of military drones is a function of the relative capabilities of the attacking side and of the defensive side.

Second, since current-generation drones carry limited munitions, they cannot identify and acquire long-range target, and they are vulnerable to air defense and electronic warfare systems, we speculate that they will more extensively and effectively used by the stronger side: the actor possessing the combined set of capabilities for long-range detection, real-time secure communications, electronic warfare, and precision-strike, among others. Formally, we expect that

H2: the employment of drones will not strengthen the weaker side, but further exacerbate battlefield imbalances of forces.

Third, we derive that there is no reason why drones make close combat obsolete. To conquer and control enemy territory, ground troops are necessary. However, as conflicts in Afghanistan and Iraq have shown, skilled and proficient ground troops can take advantage of the natural environment for concealment, and create significant troubles for very skilled and well-equipped militaries. Accordingly,

H3: the employment of military drones will not relieve countries from the need to engage in close ground combat.

Empirical Cases

In the following sections, we test the drone revolution thesis on three recent conflicts which have observed extensive employment of unmanned aerial vehicles and, at the same time, have been hailed as basket-cases of the revolutionary effect that drones have on the battlefield: the War in Libya (2019-2020), the War in Syria (2011-2020) and the Nagorno-Karabakh War (2020).

The Drone War in Libya, 2019-2020

In 2011, NATO military operation *Odyssey Down/Resolute Support* ended Muammar Qaddafi's 42 year-long rule over Libya.[93] A civil war soon ensued among multiple factions, tribes, mercenaries, and the Islamic State (ISIS).[94] In 2015, two main actors emerged: the Tripoli-based, UN-recognized, and Turkey-backed Government of National Accord (GNA), led by Fayez al-Serraj and in control of the country's western coastal area; and the Tobruk-based Libyan National Army (LNA) led by General Khalifa Haftar, in control of the eastern coastal and continental area, and supported by Russia, the United Arab Emirates and Egypt.[95] In this section, we analyze the extensive use of drones in the so-called 2019-2020 "Western Libyan Campaign": the fight between the GNA and the LNA for the control of Tripoli and of the western coastal part of Libya (Tripolitania).[96] Between April and November 2019, the Libya civil war observed over 1,040 recorded drone strikes, prompting the UN Special Representative to Libya, to speak of "the largest drone war in the world."[97] The Libyan civil war thus represents an ideal case to test the drone revolution thesis also because some argued the deployment of drones in this conflict was a "game changer", with major implications for the very "future of warfare".[98] In fact, the empirical record

[93] Christopher S. Chivvis, *Toppling Qaddafi: Libya and the Limits of Liberal Intervention* (Cambridge: Cambridge University Press, 2013).
[94] Christopher S. Chivvis and Jeffrey Martini, *Libya After Qaddafi Lessons and Implications for the Future* (Santa Monica, CA: RAND Corporation, 2014).
[95] Wolfram Lacher, *Libya's Fragmentation: Structure and Process in Violent Conflict* (London: Bloomsbury Publishing, 2020).
[96] While the 2011 war was probably "the first real drone war", there is no significant evidence of use of drones between 2015 and 2018. See Spencer Ackerman, "Libya: The Real U.S. Drone War," *Wired*, October 29, 2011, p. 217 and Dan Gettinger, "The Drone Databook", *The Center for the Study of the Drone at Bard College*, October 2019, https://dronecenter.bard.edu/files/2019/10/CSD-Drone-Databook-Web.pdf.
[97] Ghassan Salamé, "Security Council Meeting No. 8667", November 18, 2019, https://www.un.org/press/en/2019/sc14023.doc.htm and https://www.youtube.com/watch?v=IB3jie4i7SI
[98] Jalel Harchaoui of the Clingendael Institute noted that Turkey's use of its TB2 in Libya had been a "game changer" thanks to the Turkish capability to evolve and improve the performance of their drones. See Kington Tom, Libya is turning into a battle lab for air warfare, *Defense News*, August, 6, 2020, https://www.defensenews.com/smr/nato-air-power/2020/08/06/libya-is-turning-into-a-battle-lab-for-air-warfare/; Vest, Nathan and Colin Clarke, "Is the Conflict in Libya a Preview of the Future of Warfare? *Defense One*, June 2, 2020, https://www.defenseone.com/ideas/2020/06/conflict-libya-preview-future-warfare/165807/

does not support this visionary interpretation: drones did not yield an offensive advantage, they did not level the playing field and they did not cancel close combat and force employment.

Offensive advantage

The first premise of the drone revolution perspective holds that drones yield an offensive advantage. In operational terms, this means that drones are capable of neutralizing modern air defense systems and thus they enjoy air impunity. In fact, in Libya, drones "[have not been] operated with impunity."[99] Between early 2019 and mid 2020, the GNA lost 22 out of its 24 drones in operations.[100] Similarly, LNA lost 9-to-11 drones out of the estimated 20-to-30 it possessed.[101] Second, and consistent with our argument, attrition rates among combat drones strongly correlate with the presence and capabilities of the air-defense systems deployed by the enemy. In the initial phase of the conflict, the LNA had access to the capable UAE-supplied Russian *Pantsir* S-1 short-range air-defense systems: as a result, GNA's drones were decimated and their operations quickly brought to a halt.[102] The GNA had, in contrast, only less performing anti-aircraft artillery and man-portable air defense systems which not significantly affect the LNA's drone campaign.[103] However, the tide turned in November 2019, when, in support of the GNA, Turkey deployed in the airports of Misrata and Mitiga its more advanced *KORAL* electronic warfare systems and two *HAWK II* surface-to-air batteries.[104] This enabled the GNA to repeatedly shoot down LNA's drones and blind its air-defenses.[105]

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[99] Franz-Stefan Gady, "Useful, but not decisive: UAVs in Libya's civil war", *The International Institute for Strategic Studies*, November 22, 2019, https://www.iiss.org/blogs/analysis/2019/11/mide-uavs-in-libyas-civil-war

[100] Pack Jason and Pusztai Wolfgang, "Turning the Tide, how Turkey won the war for Tripoli", *Middle East Institute*, Policy Paper, November 2020, p. 5, https://www.mei.edu/sites/default/files/2020-11/Turning%20the%20Tide%20-%20How%20Turkey%20Won%20the%20War%20for%20Tripoli.pdf

[101] According to analysts "up to six *Bayraktar* [of GNA] and at least one *Wing Loong* [of LNA] have been lost" during 2019, and in the first half of 2020 16 TB2 operated by the GNA and 8 *Wing Loong* operated by LNA either crashed or were intercepted. Data from Drone Crash Database, last updated February 24, 2021, https://dronewars.net/drone-crash-database/ and Gady, *Useful, but not decisive.*

[102] Pack and Pusztai, *Turning the Tide*, p. 5; Paul Iddon, "Turkey is fighting a formidable drone war in Libya", *Ahval*, September 14, 2019, https://ahvalnews.com/libya/turkey-fighting-formidable-drone-war-libya

[103] Pack and Pusztai, *Turning the Tide,* p. 5. Specifically, these system have a 10km-range and 6km-altitude, 3.5km altitude, respectively.

[104] Pack and Pusztai, *Turning the Tide,* p. 5.

[105] Pack and Pusztai, *Turning the Tide,* p. 5.

Levelling effect

According to the drone revolution thesis, drones are cheaper to buy, easy to operate and able to neutralize air-defense systems: this would enable smaller, more resource-scarce and even weaker actors to confront, and eventually even defeat, more powerful adversaries. The civil war in Libya supports the opposite interpretation: far from levelling the playing field, in the Western Libyan Campaign, drones have exacerbated battlefield imbalances. First, drones were more widely and more effectively used by the stronger side.[106] In early 2019, the first part of the civil war, the LNA was the strongest actor: UAE, Russia and Egypt provided support in terms of logistics, communications, drones, anti-air defense systems and other military equipment, and beside its own fleet of jet fighters, the LNA could also count on the support of those supplied by its allies (like MiG-21s, MiG-23s, *Mirage* 2000s, F-16s *Fighting Falcon* and allegedly also *Rafales*).[107] As seen in the previous section, in this phase, the LNA could use its drones more effectively.

[106] The GNA had 12-to-24 drones, while the LNA employed 20-to-30 drones. Gady, *Useful, but not decisive*, and Pack and Pusztai, *Turning the Tide*. For the LNA, we could not find any specific data about availability of drones. Multiple sources such as Bellingcat, RAND and IISS Military Balance 2018-2020. For this reason, we employed a conservative coding strategy, and we used data about all the drones acquired by UAE from China between 2010 and 2020, which amount to 15 in 2017 and 25 in 2018. See the SIPRI and ISPI data. https://www.ispionline.it/en/pubblicazione/middle-easts-game-drones-race-lethal-uavs-and-its-implications-regions-security-landscape-28902 The SIPRI Stockholm International Peace Research Institute claimed that China delivered 40 drones to the UAE in the period 2010-2020. For Gady the LNA had 8 Wing Loong I and "some" Wing Loong II. As a conservative coding, we assume "some" equal to 12. See Gady, *Useful, but not decisive,* and Bruce Einhorn, "Combat Drones Made in China Are Coming to a Conflict Near You", *Bloomberg*, March 17, 2021, https://www.bloomberg.com/news/articles/2021-03-17/china-s-combat-drones-push-could-spark-a-global-arms-race

[107] Garrett Reim, "Record number of UAV shoot downs prompt new USAF tactics and countermeasure pod", *Flight Global*, June 30, 2020, https://www.flightglobal.com/military-uavs/record-number-of-uav-shoot-downs-prompt-new-usaf-tactics-and-countermeasure-pod/138908.article; Pack and Pusztai, *Turning the Tide*, p. 4-5 and The International Institute for Strategic Studies, *The Military Balance 2019* (London, UK: IISS, 2019), p. 356. The United Arab Emirates deployed in Libya at least 6 AT-802, 2 UH-60M and 2 Wing Loong I (GJ-1) UAV in 2019. See The International Institute for Strategic Studies (IISS), *The Military Balance 2019*, p. 356; Itamilradar, "UAE Mirages deployed in Egypt", *Itamilradar*, May 7, 2020, https://www.itamilradar.com/2020/05/07/uae-mirages-deployed-in-egypt/.

Second, and related, in contrast to the drone revolution thesis, drones did not enable the weaker side, the GNA, to overcome its tactical and strategic inferiority: lacking military capabilities and external support, as seen, the GNA was in fact not even able to carry out drone strikes during the early phase of the Western Libya campaign, due to LNA air superiority.

Third, consistently with our modern system of force employment in air warfare, the introduction of drones in the theater did not alter the balance of forces. Between May and July 2019, Turkey provided the weaker side, the GNA, with 12 *Bayraktar* TB2 drones. However, they did not allow the GNA to contest LNA's military superiority. Quite the contrary, strong of its command of the air, in the span of a few months the LNA "virtually eradicated from the aerial battlefield" GNA's newly acquired drones.[108] However, as discussed above, when Turkey provided the GNA with both air defense and electronic warfare systems, the tactical balance shifted: such systems addressed GNA's vulnerabilities and permitted its forces to offset LNA's capabilities. Supported by Turkish electronic warfare capabilities, the GNA could then launch its own campaign of drone strikes, which ultimately helped tilt the military balance and hence the course of the conflict.[109]

Interestingly, at no point we found evidence that the weaker party could quickly and cheaply generate drones to offset its combat losses, tactical inferiority or strategic imbalance. Additionally, and further in contrast to the drone revolution thesis, all drones operating in Libya were foreign-made, foreign-supplied, and foreign operated.[110]

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108 Pack and Pusztai, *Turning the Tide*, p. 5; Baykar official Website, TB2 Bayraktar technical specifications, https://baykardefence.com/uav-15.html; Iddon, *Turkey is fighting a formidable drone war in Libya*; The International Institute for Strategic Studies (IISS), *The Military Balance 2019*, p. 356; Pack and Pusztai, *Turning the Tide,* Pp. 4-14.

109 Ben Fishman and Conor Hiney, "What Turned the Battle for Tripoli?", *Washington Institute*, May 6, 2020, https://www.washingtoninstitute.org/policy-analysis/view/what-turned-the-battle-for-tripoli

110 Pilots from the United Arab Emirates (UAE) stationed at the Al Khadim airbase (south of Tripoli) operated in fact the LNA's Chinese drones, while Turkish personnel operated its domestically produced drones from airfields in Misrata and Mitiga. See Gady, *Useful, but not decisive*; Al Jazeera, "Erdogan: Turkey will increase military support to GNA if needed", *Al Jazeera*, December 22, 2019, https://www.aljazeera.com/news/2019/12/22/erdogan-turkey-will-increase-military-support-to-gna-if-needed and Pack and Pusztai, *Turning the Tide.* A similar number of Turkish attack drones (20) is also reported by some media. See Thomas Harding, "Revealed: How Turkey ramped up Libyan drone attacks to escalate conflict", *The National News*, July 20, 2020, https://www.thenationalnews.com/world/revealed-how-turkey-ramped-up-libyan-drone-attacks-to-escalate-conflict-1.1051869; See respectively Gady, *Useful, but not decisive;* The International Institute for Strategic Studies (IISS), *The Military Balance 2020*, p. 365; Alex Gatopoulos, "'Largest drone war in the world': How airpower saved Tripoli",

Last but not least, traditional force structures have remained fundamental both in enabling drone strikes and in neutralizing the adversary's. In the battles for Western coastal Libya, drone operations have been useful but not decisive. In fact, the final outcome of the war has been largely affected by the massive Turkish intervention (artillery, drones, radar, PCMs, armored vehicles and frigates)[111] and by the inaction of foreign countries in support of the LNA.

Close Combat and Force Employment

The last premise of the drone revolution thesis is that, by democratizing long-range precision-strike, drones enable actors to fight from distance, thus cancelling close combat and consequently making tactical and operational force employment less and less relevant. If this argument is correct, we should find three types of evidence: first, close combat should have disappeared; second, combat skills and proficiency in traditional force employment, like the capacity to exploit cover and concealment, should have lost relevance; and finally, traditional force structures, or combined arms warfare, should have also provided lesser contributions to combat outcomes. In fact, the war in Lybia shows the opposite.[112]

First, close combat has not disappeared. In order to take Tripoli, on 4 April 2020, for instance, LNA launched a new offensive. However, given the risk of getting drawn into urban warfare, with heavy civilian casualties, the LNA employed "a cat-and-mouse military maneuver that sought to draw the anti-LNA forces into the open or the outskirts of the city" where lack of buildings exposed targets to enemy weapons.[113] Beside artillery and airpower, both the LNA and

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Al Jazeera, May 28, 2020, https://www.aljazeera.com/news/2020/5/28/largest-drone-war-in-the-world-how-airpower-saved-tripoli and Pack and Pusztai, *Turning the Tide*, p. 4. According to the IISS, "at least two UAE-owned Schiebel *Campopter* S-100 rotary UAVs have also been deployed, as well as an unknown number of Iranian-made *Mohajer*-2 UAVs". The *Wing Loong II* are responsible for the majority of the 800 strikes conducted by the LNA between April to November 2019.

111 Gianandrea Gaiani, "I turchi sbarcano a Tripoli artiglieria e cingolati da combattimento," *Analisi Difesa*, February 1, 2020, https://www.analisidifesa.it/2020/02/a-tripoli-i-turchi-sbarcano-artiglieria-e-cingolati-da-combattimento/

112 The Battle for Tripoli started as an attempt by the LNA to conquer the capital of Libya Tripoli. As the LNA conquered territory surrounding the city, the battle became a siege of the city. As the GNA regained momentum, the battle expanded to the rest of Tripolitalia.

113 Pack and Pusztai, *Turning the Tide*, p. 3.

the GNA relied on infantry units, in particular to take control strategic infrastructures, like airports, highways and crossroads. Mercenaries were also significantly employed, not in infantry battles, but to to hold and defend strategic positions, for land advances, to retake terrain, or to execute mopping-up operations.[114] From May 2019 GNA's military leaders started to hire mercenaries from Chad and Darfur. Afterwards in December 2019, Turkey started to deploy well-trained mercenaries from Syria as ground troops in order to support al-Sarraj forces. From about 1.000 Syrians deployed in January 2020, the number rose to about 15.000 in the summer.[115] On the other side, LNA hired troops from Libyan Toubou, Sudan and Chad in order to defend oil installations, fields and airstrips, furthermore in August, the Wagner Group increased its support to Haftar mainly with tactical assistance and ISR operations for artillery and aerial strikes.[116] Turkey's deployment of its surface-to-air missile batteries *HAWK XXI* in the airports of Misrata and Mitiga and of its *KORAL* electronic warfare systems ended LNA's air superiority but, more importantly, allowed the GNA to counterattack: without the counter-attack, the siege of Tripoli would not have ended.[117] Importantly, however, GNA's counterpunch was also fundamentally aided by Turkish organizational and infrastructural support, including intelligence, reconnaissance and communications.[118]

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[114] Pack and Pusztai, *Turning the Tide*, p. 10.

[115] For the report of the Syrian Observatory for Human Rights (SOHR) about the number of Turkish-backed mercenaries in Libya see: SOHR, "SOHR Says Total Number Of Syrian Mercenaries In Libya Has Risen To 15,800", *SOHR*, July 10, 2020, https://www.syriahr.com/en/174204/; H. Tayea, "SOHR: Turkey Deployed 15,300 Turkish-Backed Mercenaries in Libya", *See*, July 5, 2020, https://see.news/sohr-number-of-syrian-mercenaries-in-libya-rises-to-153/; and The Arab Weekly, "Reports shed light on mercenaries, terrorists sent by Turkey to Libya", *The Arab Weekly*, July 18, 2020, https://thearabweekly.com/reports-shed-light-mercenaries-terrorists-sent-turkey-libya. The Middle East Institute reported that "about 500 Syrians mercenaries had been killed and more than 2.000 wounded by June 2020", https://www.mei.edu/publications/turning-tide-how-turkey-won-war-tripoli.

[116] Pack and Pusztai, *Turning the Tide*, p. 9.

[117] Itamilradar, "Turkish 'Hawk' Deployed in Tripoli", *Itamilradar*, January 18, 2020, https://www.itamilradar.com/2020/01/18/turkish-hawk-deployed-in-tripoli/; Fishman and Hiney, *What Turned the Battle for Tripoli?,* https://www.washingtoninstitute.org/policy-analysis/view/what-turned-the-battle-for-tripoli

[118] Pack and Pusztai, *Turning the Tide*, p. 12; https://t-intell.com/2020/05/22/lethal-stalkers-how-turkish-drones-are-neutralizing-haftars-pantsirs-in-libya-bda/; https://www.defensenews.com/smr/nato-air-power/2020/08/06/libya-is-turning-into-a-battle-lab-for-air-warfare/ Media reported that: "Unconfirmed reports claim GNA's Turkey-supplied Bayraktar TB2 and Anka-S armed drones to have destroyed at least 20 Pantsir air defense systems, ground targets and warplanes". See Aishwarya Rakesh, "Turkish Drones in Lybia, EW Systems in Syria. 'Game Chaning': UK Defense Secretary, *Defense World*, July 15, 2020, https://www.defenseworld.net/news/27424/Did_UK_s_Defense_Secretary_Praise_Turkey_s_Drones__EW_Systems_#.X9DmtC1aau4; Gatopoulos, *Largest drone war in the world*, https://www.aljazeera.com/news/2020/5/28/largest-drone-war-in-the-world-how-airpower-saved-tripoli

Second, combat skills and proficiency in traditional force employment have not lost relevance. For instance, Turkey's *KORAL* helped GNA forces detect, locate, jam, target and destroy LNA's *Pantsir* S-1 air defenses. Interestingly, however, the tactical balance changed again in May 2020 when, by deactivating their radars, and switching to electro-optical sensors, LNA's air-defenses system operators could avoid Turkish electronic warfare jamming and detection.[119] This procedural change granted cover and concealment in the electromagnetic spectrum: as a result, "several Turkish combat drones [operated by GNA] were shot down […although] it was already too late to have a real impact on the battlefield dynamics."[120]

Last but not least, traditional force structures have remained fundamental both in enabling drone strikes and in neutralizing the adversaries. In the battles for Western coastal Libya, drone operations have been useful but not decisive. In fact, the final outcome of the war has been largely affected by the massive Turkish intervention (mercenaries, artillery, drones, radar, PCMs, armored vehicles and frigates)[121] and by the inaction of foreign countries in support of the LNA.

The Drone War in Syria, 2011-2020

Started in 2011 as a result of the Arab Spring, the Syrian Civil War can be divided in three different campaigns: the clash between the Syrian government, its allies and various anti-government forces, including ISIS and al-Nusra; Turkey's military operations against the Kurds in Northeast Syria; and the international coalition efforts to defeat ISIS.[122] Several external actors, at different stages, and for different reasons, joined the fight: Russia, Iran and Hezbollah intervened in support of the

[119] Technical appendix.
[120] Pack and Pusztai, *Turning the Tide*, p. 12.
[121] Gianandrea Gaiani, "I turchi sbarcano a Tripoli artiglieria e cingolati da combattimento," *Analisi Difesa*, February 1, 2020, https://www.analisidifesa.it/2020/02/a-tripoli-i-turchi-sbarcano-artiglieria-e-cingolati-da-combattimento/
[122] The three campaigns overlap significantly in terms of time-span and military activities. However, this distinction is analytically useful to understand the role how different actors have used drones in the complex patchwork of the Syrian conflict.

Assad regime; while the United States, Turkey, and Saudi Arabia among others supported different anti-government forces and, in the case of the United States and its allies, fought ISIS.[123]

Drones have been used extensively in all three campaigns. In fact, many have described Syria as "the most drone-dense conflict to date" with "military, commercial, hobbyist, and homemade models taking to the skies on all sides."[124] Similarly to the Libyan case, the role of drones in the Syrian war has not only attracted significant attention but also led to speculations about their revolutionary implications for modern warfare.[125] As we show in the following sections, however, the Syrian case does not lend support to the drone revolution perspective. Coherently with our modern system of force employment in air warfare, drones did not grant an offensive advantage, they did not level the playing field and did not cancel close combat.

Offensive advantage

Like in Libya, there is no evidence that drones yielded an offensive advantage in Syria. In fact, they experienced significant attrition to the point that in 2017 there were "dropping like flies from the sky."[126] Iran, for instance, was the primary user of drones in Syria: in December 2013, rebels shot down its small UAV *Yasir* in Qalamoun, between 2015 and 2016, Turkey's armed forces repeatedly shot down several heavier Iranian drones, such as the *Shaded* 129, and US air defense systems repeatedly shot down several *Shaded* between 2016 and 2019.[127] Russia also deployed significant

[123] Cristopher Phillips, *The battle for Syria: International rivalry in the new Middle East* (New Haven: Yale University Press, 2016); Nikolaos Van Dam, *Destroying a nation: The civil war in Syria* (London: Bloomsbury Publishing, 2017); Robin Yassin-Kassab, and Leila Al-Shami, Burning Country: Syrians in Revolution and War (London: Pluto Press, 2018).

[124] Dan Gettinger, *Drones operating in Syria and Iraq*, Center for the Study of the Drone, Bard College, December 2016, pp. 14 - 15.

[125] Larry Friese, "Emerging unmanned threats: the use of commercially-available UAVs by armed non-state actors," *Armament Research Services (ARES)*, February 2016, https://armamentresearch.com/wp-content/uploads/2016/02/ARES-Special-Report-No.-2-Emerging-Unmanned-Threats.pdf; Mariya Petkova, "Turkish drones – a 'game changer' in idlib," *Al Jazeera*, March 2, 2020, https://www.aljazeera.com/news/2020/3/2/turkish-drones-a-game-changer-in; Fukuyama, "Droning On in the Middle East."

[126] Tom Cooper, "Drones Are Dropping Like Flies From the Sky Over Syria. Shoot-downs are becoming commonplace", *War is Boring*, June 22, 2017, https://warisboring.com/drones-are-dropping-like-flies-from-the-sky-over-syria/.

[127] Gettinger, *Drones operating in Syria and Iraq*, p. 7. See also Syria Mubasher, "Downing of a reconnaissance plane in the Qalamoun region 7 12 2013", last accessed June 25, 2021, https://www.youtube.com/watch?v=MyshPGpVo3Y; Hussam Al Marie, Twitter post May 16, 2015. https://twitter.com/HussamAlMarie/status/599585335522263040

drones in support of its intervention in Syria: like for Iran, its *Orlan*-10 have been decimated by Turkish air-defense systems and were shot down even by Jaish al-Izzah rebel forces.[128]

During the war in Syria, Russian air defense systems suffered, however, significant losses, leading many to draw major conclusions about drones' alleged offensive advantage.[129] Available evidence warrants caution. On the one hand, Russian air defense systems proved capable of neutralizing most drone threats. In January 2018, for instance, Russian short-range air-defense systems managed to destroy 7 incoming unmanned vehicles, and "Russian specialists of the electronic warfare units managed to seize control of the remaining drones" launched by anti-Assad groups against Russia's bases in Tartus and Khmeimim.[130] Similarly, between 2018 and 2020, Russian air defenses disabled over 150 drones and in 2019 alone, Russia managed to neutralize around 60 multiple drone-and-missile attacks against its Khmeimim air base.[131] Similarly, when in in March 2020 Syria deployed Russian short-range air-defense systems in Idlib, in the span of few days it could shoot down 10 Turkish drones, and according to Russian experts these systems "stabilized the balance in the battlefield and permitted the Syrian Army to regain the strategic city

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Gettinger, *Drones operating in Syria and Iraq*, p. 8; Guillaume Lasconjarias and Hassan Maged, "Fear the Drones: Remotely Piloted Systems and Non-State Actors in Syria and Iraq," *Research Paper*, No. 77 (Paris: Institut de Recherche Stratégique de l'Ecole Militaire, 4 September 2019) p. 6; "How U.S. F-15E Drone Shoot-Down Changed Air Game in Syria," *Aviation Week Network*, September 18, 2017, https://aviationweek.com/defense-space/aircraft-propulsion/how-us-f-15e-drone-shoot-down-changed-air-game-syria; Phil Stewart, "In Syrian Skies, U.S. Pilots Learn How Fast Air War Can Morph," *Reuters*, August 28, 2017, https://www.reuters.com/article/us-usa-syria-pilot-idUSKCN1B80CA. On US operations against Iranian drones see also Michael R. Gordon, "U.S. Says It Shot Down Drone That Attacked Fighters in Syria," *New York Times*, June 8, 2017, https://www.nytimes.com/2017/06/08/world/middleeast/syria-drone-shot-down.html, and Julian Borger, "US Shoots Down Second Iran-Made Armed Drone over Syria in 12 Days," *The Guardian*, June 20, 2017, https://www.theguardian.com/us-news/2017/jun/20/us-iran-drone-shot-down-syria.

127 Reuters Staff, "Turkish PM Davutoglu says downed drone was Russian-made: TV", *Reuters* (October 19, 2015), https://www.reuters.com/article/us-mideast-crisis-syria-turkey-idUSKCN0SD12620151019. See also Gettinger, *Drones operating in Syria and Iraq*, p. 10.

128 Reuters Staff, "Turkish PM Davutoglu says downed drone was Russian-made: TV", *Reuters* (October 19, 2015), https://www.reuters.com/article/us-mideast-crisis-syria-turkey-idUSKCN0SD12620151019. See also Gettinger, *Drones operating in Syria and Iraq*, p. 10.

129 Among the systems destroyed, there is evidence of successful attacks against short-range systems like the *Pantsir*-S and Buk-M1-2 (NATO classification: SA-17 *Grizzly*), as well as medium-range systems like surface-to-air missile batteries, the S300 (SA-10 *Gramble*), and S-400 *Triumpf* (SA-21 *Growler*) High Altitude Air Defense Systems (HIMADS).

130 Ridvan Bari Urcosta, "The Revolution in Drone Warfare. The Lessons from the Idlib De-Escalation Zone", *European, Middle Eastern and African Affairs*, Fall 2020, p. 51.

131 Sameer Joshi, "Drone Swarms: The Next Evolution in Warfare", *Raksha Anirveda,* February 8, 2021, http://www.raksha-anirveda.com/drone-swarms-the-next-evolution-in-warfare/; Urcosta, *The Revolution in Drone Warfare*, p. 51.

of Saraqib."[132] On the other hand, Russian air defense systems were not always extremely effective. However, as we discuss in the following section, this was more a question of force employment – proficiency and coordination – than a result of drones' revolutionary capabilities.

Levelling effect

Like in Libya, there is no evidence that drones represented an equalizing force in the Syrian War. First, although drones operated by rebel groups and non-state actors generated enormous concern and attention, overall they were scarcely effective. ISIS drones', for instance, were easily neutralized and achieved only limited results against Russian armed forces and equipment.[133] Similarly, Syrian rebel groups employed their small and rudimentary UAVs mostly for surveillance or for dropping small bombs: this, however, did not have any major effect on the battlefield.[134]

Second, drones have generally amplified existing asymmetries in power. For instance, U.S. armed forces effectively used their UAVs for targeted killing, for striking light armored vehicles, for hunting snipers and for detecting concealed explosive devices against ISIS.[135] Similarly, Turkish

132 Hasan Hiz, SİHA'lar İdlib harekatını tarihe geçirdi: "Bu inanılır gibi değil, tanksavar kullanmaya kalksanız aylar sürer," *YeniSafak*, February 29, 2020, https://www.yenisafak.com/dunya/sihalar-idlib-harekatini-tarihe-gecirdi-bu-inanilir-gibi-degil-tanksavar-kullanmaya-kalksaniz-aylar-surer-3527623. Linguistic appendix.

133 Thomas Grove, "Drone Attacks on Russian Bases in Syria Expose Security Holes", *The Wall Street Journal*, January 15, 2018, https://www.wsj.com/articles/drone-attacks-on-russian-bases-in-syria-expose-security-holes-1516017608; Don Rassler, *The Islamic State and Drones: Supply, Scale, and Future Threats* (West Point, NY: Combating Terrorism Center, 2018); T.S. Allen, Kyle Brown and Jonathan Askonas, "How the Army out-innovated the Islamic State's Drones", *War On the Rocks*, December 21, 2020, https://warontherocks.com/2020/12/how-the-army-out-innovated-the-islamic-states-drones/; Asaad Almohammad and Anne Speckhard, "ISIS Drones: Evolution, Leadership, Bases, Operations and Logistics," *Research Report* (Washington, DC: International Center for the Study of Violent Extremism, 2017), p. 1; Shawn Snow, "Marine Artillery Barrage of Raqqa Was So Intense Two Howitzers Burned Out", *Marine Corps Times*, November 2, 2017, https://www.marinecorpstimes.com/flashpoints/2017/11/02/marine-artillery-barrage-of-raqqa-was-so-intense-two-howitzers-burned-out/.

134 Gideon Grudo, "ISIS UAS Capabilities Choked, Posing Little Threat in 2018," *Air Force Magazine*, January 26, 2018, https://www.airforcemag.com/isis-uas-capabilities-choked-posing-little-threat-in-2018/; Louisa Loveluck and Thomas Gibbons-Neff, "Islamic State Is 'Fighting to the Death' as civilians flee Raqqa," *Washington Post*, August 8, 2017, https://www.washingtonpost.com/world/middle_east/in-raqqa-a-battle-of-attrition-as-civilians-flee-in-shock/2017/08/07/1e814f9e-78f7-11e7-803f-a6c989606ac7_story.html; John Dorrian, "Department of Defense Press Briefing by Col. Dorrian via Teleconference from Baghdad, Iraq," transcript, *U.S. Department of Defense*, May 3, 2017, https://www.defense.gov/Newsroom/Transcripts/Transcript/Article/1172185/department-of-defense-press-briefing-by-col-dorrian-via-teleconference-from-bag/.

135 Adam J. Hebert, "In Case You Missed It: Airpower Killed ISIS," *Air Force Magazine*, January 29, 2018, https://www.airforcemag.com/article/in-case-you-missed-it-airpower-killed-isis/; W. J. Hennigan, "US Leans on Risky Drone Strikes in Urban Syrian Fight," *Stars and Stripes*, August 19, 2017, https://billingsgazette.com/ap/national/us-leans-on-risky-drone-strikes-in-urban-syrian-fight-copy/article_1d2dd1dc-76f0-54a4-b9a7-61dfcf758c19.html.

Bayraktar TB2, armed with MAM-L missiles, despite their limited effectiveness against heavy armed vehicles and fortified positions, scored important successes against significantly more resource-scarce adversaries like Kurdish rebel groups.[136]

Third, there is no available evidence suggesting that weaker actors could deploy more drones or quickly ramp up drone production to offset combat losses or its overall inferiority. In fact, there is no evidence that the Assad regime, the Syrian Kurds, ISIS and other minor rebel forces which, at different stages, were on the verge of collapse, could quickly produce and deploy drones to launch a counter-offensive.[137] In contrast, the Syrian government survived thanks to the intervention of regional and great powers like Iran and Russia which, in turn, deployed their troops and military assets.[138] Russia did not even deploy strike-capable drones, given that its defense industrial base is unable to produce them, while Iran's suffered from several technological limitations. Similarly, Syrian Kurds and other rebel forces needed the support of the United States to withstand the pressure from ISIS and the Syrian government. Finally, although enormous attention has been devoted to the use of drones by ISIS, as the group started being encircled, it did not rely on drones to oppose enemy advances. Interestingly, and further disconfirming the drone revolution thesis, like in Libya, drones operating in Syria were mostly foreign-made, foreign-supplied, and foreign operated.[139]

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136 Mini Akıllı Mühimmat, Thermobaric Smart Micro Munition. See Scott Crino and Andy Dreby, "Turkey's Drone War in Syria – A Red Team View", *Small Wars Journal*, April 16, 2020, https://smallwarsjournal.com/jrnl/art/turkeys-drone-war-syria-red-team-view; Christian Clausman, "Combat RPAs Integral in Defeating ISIS," *Air Force News Service*, December 5, 2017, https://www.af.mil/News/Article-Display/Article/1388206/combat-rpas-integral-in-defeating-isis/.

137 Carla E. Humud and Christopher M. Blanchard, "Armed Conflict in Syria: Overview and U.S. Response," *CRS Report*, No. RL33487 (Washington, DC: Congressional Research Service, 2020); Becca Wasser, Stacie L. Pettyjohn, Jeffrey Martini, Alexandra T. Evans, Karl P. Mueller, Nathaniel Edenfield, Gabrielle Tarini, Ryan Haberman and Jalen Zeman, *The Air War Against the Islamic State The Role of Airpower in Operation Inherent Resolve* (Santa Monica, CA: RAND Corporation, 2021).

138 Samuel Charap, Elina Treyger and Edward Geist, *Understanding Russia's Intervention in Syria* (Santa Monica, CA: RAND Corporation, 2019); Seth G. Jones, *Moscow's War in Syria* (Washington, DC: Center for Strategic and International Studies, 2020); Robert E. Hamilton, Chris and Aaron Stein, *Russia's War in Syria: Assessing Russian Military Capabilities and Lessons Learned* (Philadelphia, PA: Foreign Policy Research Institute 2020); Mason Clark, *The Russian Military's Lessons Learned in Syria* (Washington, DC: Institute for the Study of War, 2021).

139 Some analysts have paid significant attention to the use of drones by non-state actors like Hezbollah, ISIS and al-Nusra. However, none of them deployed anything bigger than small drones used for terror-like attacks or ambushes against individual targets.

Close combat and force employment

In the case of Syria, we do not find evidence that close combat disappeared, that combat skills and proficiency have lost relevance and that traditional force structures, or combined arms warfare, have proved less important in determining battle outcomes.

First, the most dramatic disconfirmation of the drone revolution thesis comes from the intensity and extension of close combat observed during the Syrian Civil War.[140] Overall, the conflict has produced a death toll between 100,000 and 500,000 casualties to which one should add the displaced.[141] This was the result of ongoing cycles advances, sieges, frontal clashes, retreats and counter-offensives as seen in several key battles including in Damascus, Walamous, al-Yaarybiyah, Aleppo, Idlib, Yarmouk, and Raqqa, just to name a few.[142] The Syrian armed forces along with their Iranian and Russian supporters massively relayed on standoff fire through artillery, attack helicopters of air-to-ground bombers.[143] However, even these fairly undiscriminated use of short-range fire failed to cancel close combat: most campaigns continued in fact either with sieges or with government forces storming towns and cities.[144] The same applies to ISIS and other rebel groups which massively relied on guerrilla tactics and modern warfare approaches to penetrate enemy lines and gain territory. Interestingly, both the Syrian government and Iranian forces fired ballistic missiles against the rebels in 2012 and 2017 and 2021, respectively, while the Syrian government relied on chemical weapons multiple times between 2021 and 2021.[145] These cases further question the drone warfare narrative: if drones are so easy, quick and cheap to produce and, at the same time, they are so effective, why did these actors rely on these economically and politically more expensive alternatives?

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140 Cercare nota
141 Cercare nota
142 Cercare nota
143 Air power syria
144 storming
145 Daryl Kimball and Kelsey Davenport, "Timeline of Syrian Chemical Weapons Activity, 2012-2021," Arms Control Association, https://www.armscontrol.org/factsheets/Timeline-of-Syrian-Chemical-Weapons-Activity.

Second, and related, combat skills and proficiency related to the modern system of force employment remained fundamentally important throughout the conflict. A perfect testbed for this proposition regards the alleged vulnerability of Russian air-defense systems to rebels' drones. Granted that detecting, tracking and engaging small targets flying at low altitude "remains a major challenge", especially for long-range systems (like the S-300V4 and the S-400), asymmetries in the modern system of force employment explain these cases.[146] On the one hand, Syrian officers' limited experience and relatively scarce skills at operating air-defense systems exposed theirs positions to enemy fire.[147] On the other, Syria's adversaries proved remarkably skilled and proficient in the suppression of enemy air defenses. Most prominently, in the battle for Idlib, in North-east Syria, between December 2019 and March 2020, Turkish troops were extremely effective in coordinating the employment of different platforms, systems and countermeasures against Syrian surface-to-air batteries: they employed their electromagnetic spectrum (EMS) warfare systems to tap into Syrian Army's phones to geolocate them; through their advanced *KORAL* multi-functional systems, they jammed, deceived, and blinded Russian anti-air defense systems; next, they used their TB2 Bayraktar and *Anka*-S drones to attack and destroy these targets.[148] Interestingly, Turkey's military advantage was abruptly halted when the Syrian Army and its local allies adopted stricter operational security measures: they stopped using cell phones, switched to paper-based communications, and thus exploit "cover and concealment" also in the electromagnetic spectrum.[149]

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[146] Guy Plopsky, "Russia's Air Defenses in Syria: More Politics than Punch", *The Begin-Sadat Center for Strategic Studies* October 18, 2017, https://besacenter.org/perspectives-papers/russia-air-defense-syria/. For instance, at long range, they can realistically intercept only cumbersome targets with good radar return like air-to-air refuel, transport or AEW&C aircraft. See Technical Appendix. FOI

[147] John V. Parachini and Peter A. Wilson, "Drone-Era Warfare Shows the Operational Limits of Air Defense Systems", *RAND Corporation*, July 2, 2020, https://www.rand.org/blog/2020/07/drone-era-warfare-shows-the-operational-limits-of-air.html From the U.S. experience, we know that the performance of air-defense systems is directly associated with personnel skills and proficiency. See Bruce R. Orvis, Michael Childress, J Michael Polich, *Effect of Personnel Quality on the Performance of Patriot Air Defense System Operators* (Santa Monica: CA, RAND Corporation, 1992).

[148] Urcosta, *The Revolution in Drone Warfare*, p. 52; Gatopoulos, *Battle for Idlib*; Data was actually first transmitted to drones (the TAI Anka) used as communication relays, which in turn then passed it to combat drones at longer distance.

[149] Urcosta, *The Revolution in Drone Warfare*, p. 52.

The battle for Idlib deserves attention also because of the large-scale, and effective, use of drones in coordinated squadron-strong attacks. Importantly, however, Turkish troops were also very successful in exploiting geographical and morphological factors to their advantage.[150] Located in proximity to the Turkish border, the operation in Idlib granted Turkish armed forces significantly easier intelligence, surveillance, reconnaissance, target acquisition and sequential strike. By using squadron-strong drone attacks, Turkey could achieve "high precision long-range strikes, enabling Turkey to bypass the Idlib airspace yet managing to inflict heavy casualties to Syrian Arab Army targets".[151] As the former director of International Affairs for Turkey's Undersecretariat for Defense Industries noted, "You take off from Turkey and are there within minutes. Targets are also very close together, which means you don't have to spend hours looking for them."[152] On the other, Syrian armed forces showed very limited competence in locating their air defenses systems which were hence only scarcely able to defend themselves and exposed to Turkey's airstrikes.[153]

Azerbaijan-Armenian Conflict over Nagorno-Karabakh, 2020

Nagorno-Karabakh is, since the 1991-94 Nagorno-Karabakh war, an Armenia-controlled enclave inside Azerbaijan's territory. On September 27, 2020, Azerbaijan tried to revert this situation with what was later known as the "44 days war". In this conflict, Azerbaijan extensively relied on drones: its successes led many to hailed the military confrontation as a turning point in warfare.[154] Some analysts claimed in fact that "Azerbaijan's drones owned the battlefield in Nagorno-

[150] Petkova, *Turkish drones – a 'game changer' in Idlib*; see also Alex Gatopoulos, "Battle for Idlib: Turkey's drones and a new way of war", *Al Jazeera*, March 3, 2020, https://www.aljazeera.com/news/2020/3/3/battle-for-idlib-turkeys-drones-and-a-new-way-of-war. By cross-checking data on the Turkish Gendarmerie's equipment with primary and secondary resources and we have estimated that it deployed around 20 ANKA-S and Bayraktar TB2 drones in Syria.
[151] Dylan Nicholson, "'Revolutionary' warfare or good marketing: Turkey's Syria drone strikes," *Defence Connect*, March 9, 2020, https://www.defenceconnect.com.au/strike-air-combat/5709-revolutionary-warfare-or-good-marketing-turkey-s-syria-drone-strikes.
[152] Quoted in Nicholson, *'Revolutionary' warfare or good marketing.*
[153] Nicholson, *'Revolutionary' warfare or good marketing.*
[154] James Rogers, "Iran and Turkey have become drone powers," *Washington Post: Monkey Cage*, January 28 2021.

Karabakh."[155] Others speculated that the systematic employment of drones led to the demise of the tank.[156] Some have gone as far as to claim that drones were a "magic bullet" which, in turn, allegedly provide conclusive evidence of an ensuing drone revolution. [157] Like in the previous cases, the empirical record does not support this reading and, in contrast, leans towards the modern system of force employment.

Offensive Advantage

Did drones yield an offensive advantage in the "44 days war" over Nagorno-Karabakh? Azeri drones suppressed Armenia's mobile air defense in the very early days of the conflict, thus prima facie lending support to speculations about an ensuing drone revolution in military affairs.[158] Azerbaijan, however, used some of the very same drones employed in Libya and Syria: what explains, then, that the same drones could achieve air impunity over Nagorno-Karabach and not in other theaters? Coherently with the modern system of force employment, the answer has little to do with drones and more to do with air-defenses: Armenia did not possess a layered air-defense

155 Robyn Dixon, "Azerbaijan's Drones Owned the Battlefield in Nagorno-Karabakh and Showed the Future of Warfare," *The Washington Post,* November 11, 2020, https://www.washingtonpost.com/world/europe/nagorno-karabkah-drones-azerbaijan-aremenia/2020/11/11/441bcbd2-193d-11eb-8bda-814ca56e138b_story.html.

156 Peter Suciu, "Does the Nagorno-Karabakh Conflict Prove the Tank is Toast? Should the tank be retired based on armor attrition in Nagorno-Karabakh?," *The National Interest,* October 5, 2020, https://nationalinterest.org/blog/buzz/does-nagorno-karabakh-conflict-prove-tank-toast-170155; "The Azerbaijan-Armenia Conflict Hints at The Future of War," *The Economist,* October 10, 2020, https://www.economist.com/europe/2020/10/08/the-azerbaijan-armenia-conflict-hints-at-the-future-of-war.

157 David Hambling, "The Magic Bullet" Drones Behind Azerbaijan's Victory Over Armenia," *Forbes*, Nov 10,2020; "The Azerbaijan-Armenia Conflict Hints at The Future of War," *The Economist*, Ocotber 8 2020; Henry Foy, "Drones and missiles tilt war with Armenia in Azerbaijan's favour," *Financial Times*, October 28 2020.

158 In the initial phase of war, Azerbajan's drones, mostly armed with Rocketsan MAM-L Smart Munitions, destroyed around 60 air defense systems, primarily 9K33 *OSA* and 9K35 *Strela* systems. The Turkish-made TB2s and the the Israeli-made *Harpy* and *Harop* also destroyed more advanced Russian-made S-300, beside several Armenian T-72 tanks and armored vehicles. See respectively Can Kasapoglu, "ANALYSIS - Five key military takeaways from Azerbaijani-Armenian war", *Anadolu Agency*, October 30, 2020, https://www.aa.com.tr/en/analysis/analysis-five-key-military-takeaways-from-azerbaijani-armenian-war/2024430; Stijn Mitzer and Joost Oliemans in collaboration with Jakub Janovsky, Dan and COIN, "The Fight For Nagorno-Karabakh: Documenting Losses On The Sides Of Armenia And Azerbaijan", *Oryx Blog*, September 27, 2020, https://www.oryxspioenkop.com/2020/09/the-fight-for-nagorno-karabakh.html; Shaan Shaikh and Wes Rumbaugh, *The Air and Missile War in Nagorno-Karabakh: Lessons for the Future of Strike and Defense* (Washington, DC: Center for Strategic & International Studies, December 8, 2020), https://www.csis.org/analysis/air-and-missile-war-nagorno-karabakh-lessons-future-strike-and-defense; Arie Egozi, "Armenia-Azerbaijan War Offers Valuable Lessons for Militaries Worldwide: An Analysis", *Raksha Anirveda* December 26, 2020, https://www.raksha-anirveda.com/armenia-azerbaijan-war-offers-valuable-lessons-for-militaries-worldwide-an-analysis/; According to Azerbaijan's president, Ilham Aliyev, Azerbaijani forces destroyed seven S-300 transporter erector launchers, two guidance stations, and one radar. https://ru.president.az/articles/48205.

system, capable of addressing a multiplicity of threats at both short- and long-range as well as low- and high-altitude. Additionally, its surface-to-air batteries – mostly Soviet platforms dating to the 1960s and 1970s – were also more obsolete than those available in Libya.[159] Some of these systems do not have signal processing and advanced functions necessary to detect, track and engage small targets.[160] Other systems do have these capabilities, but they have obsolete electronic counter-counter measures (ECCM) which render them vulnerable to enemy electronic warfare systems' jamming.[161] Moreover, Armenia had also very limited electronic warfare capabilities, which means that it could not jam or hack Azeri drones' radio communications.[162]

In sum, Azeri drones enjoyed air impunity because of the deficiencies and vulnerabilities of Armenian air defense systems.[163] As our framework suggests, mastering the modern system of force employment is challenging. In fact, because of the limited data integration between different sensors and systems, Armenian short-range air defense systems could at best detect but not intercept Azeri drones as they exploited altitude to reduce exposure to enemy fire.[164] However,

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[159] Michael Kofman and Leonid Nersisyan, "The Second Nagorno-Karabakh War, Two Weeks In", *War On the Rocks*, October 14, 2020, https://warontherocks.com/2020/10/the-second-nagorno-karabakh-war-two-weeks-in/. The systems are the 2K11 *Krug*, 9K33 *Osa*, 2K12 *Kub* and 9K35 *Strela*-10, S-300P. See Alexander Stronell, "Learning the lessons of Nagorno-Karabakh the Russian way", *International Institute for Strategic Studies*, March 10, 2021, https://www.iiss.org/blogs/analysis/2021/03/lessons-of-nagorno-karabakh

[160] For instance, at the start of the conflict, Armenia possessed the Soviet-made S-300P air-defense system – a model which was commissioned in 1978, and that most countries in the world save for Armenia, Belarus and Ukraine have decommissioned for more modern ones. While very advanced when was produced, this system had inherent vulnerabilities against small targets flying at low altitude. This limitation was addressed only in the 1980s with the introduction of moving target indicator (MTI) with ground target suppression (S300-PMU2). On the capabilities and limitations of the S300P, see Zaloga, *Soviet Air Defense Systems*, pp. 111-117; and V.S. Cherneyak, I.Ya. Immoreev, B.M. Vovshin, "Radar in the Soviet Union and Russia: A Brief Historical Outline," *IEEE Aerospace and Electronic Systems Magazine* Vol. 18, No. 12, December 2003, p. 5. On the capabilities of the S300-PMU2, see David K. Barton, "The 1993 Moscow Air Show," *Microwave Journal* Vol. 37, No. 5, May 1994, p. 30; and more generally David K. Barton, "Recent developments in Russian Radar Systems," *Proceedings International Radar Conference*, May 8-11, 1995, pp. 340-346.

[161] These are passive and active options that aim at minimizing the capacity of the enemy to interfere with the functioning of a radar. Moreover, while some of these systems have some capabilities aimed at limiting detection by enemy anti-radiation missiles (low-probability of intercept, or LPI), others do not, and thus explain why they easily failed prey of Turkish bait tactics LPI entails an intermittent emission of radar pulses in order to avoid being detected and located by enemy suppression of enemy air defense systems. See Technical Appendix.

[162] Gustav Gressel, "Military lessons from Nagorno-Karabakh: Reason for Europe to worry," *Wider Europe Blog*, (Berlin: European Council on Foreign Relations, November 24, 2020) https://ecfr.eu/article/military-lessons-from-nagorno-karabakh-reason-for-europe-to-worry/.

[163] Gressel, *Military lessons from Nagorno-Karabakh*; On plot fusion see S. J. Symons, J. A. H. Miles and J. R. Moon, "Comparison of plot and track fusion for naval sensor integration", *ISIF*, 2002, http://fusion.isif.org/proceedings/fusion02CD/pdffiles/papers/P003.pdf

[164] Which would have permitted to detect incoming threats with one system and engage it with a different one. For instance, "TB2s flew too high for these systems (like 2K11 Krug, 9K33 Osa, 2K12 Kub, and 9K35 Strela-10) to

when, late in the war, Armenia fielded more advanced electronic warfare suites, like the Russian *Polye*-21 and *Krasukha*, and more modern air defense systems, like the Russian *Buk* and *Tor*-M2KM, Azeri drones' offensive advantage waned. However, since these systems "were deployed too late in the conflict, limited in number, and vulnerable to attack themselves," they could not reverse the course of the conflict.[165]

Levelling Effect

Far from being the weapon of the weak, and a leveler of the playing field, also in the case of Nagorno-Karabakh, drones systematically favored the stronger the side, in this case Azerbaijan. First, in the two decades preceding the conflict, Azerbaijan had progressively outspent Armenia militarily by a factor of 3.5: in 2000, the two countries had similar levels of defense expenditure, Armenia $152 and Azerbaijan $141 millions; by 2020, Azerbaijan was spending $2.2bn while Armenia just $638m.[166] As a result of these differences in resources, at the outset of the conflict, Armenia possesses smaller and significantly less sophisticated military capabilities than Azerbaijan.[167]

Second, not only is Azerbaijan economically and militarily more powerful, but during the 44 days war, it was also extensively supported by a regional power, Turkey, whose help was in fact instrumental in the massive employment of drones. Such support included the very drones used, electronic warfare units, aircraft for target acquisition, long-range artillery, Turkish troops for

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intercept even if they were able to detect these relatively small aircraft." Quoted in Shaikh and Rumbaugh, *The Air and Missile War in Nagorno-Karbakh*.

165 Shaikh and Rumbaugh, *The Air and Missile War in Nagorno-Karabakh*; Stephen Bryen, "Russia knocking Turkish drones from Armenian skies," *Asia Times*, October 26 2020 https://asiatimes.com/2020/10/russia-knocking-turkish-drones-from-armenian-skies/.

166 In 2000, Armenia and Azerbaijian spent on defense $152 and $141 millions, respectively, in 2019 US$. By 2020, not only Azerbaijian was spending more, but it was spending more than three times of Armenia: $2.2bn vis-à-vis $638m. SIPRI, *Sipri Military Expenditure Database*, www.sipri.org.

167 Natalia Freyton, "Armenia-Azerbaijan War: A First-Hand Account", *Raksha Anirveda*, February 14, 2021, https://www.raksha-anirveda.com/armenia-azerbaijan-war-a-first-hand-account/; International Institute for Strategic Studies, *The Military Balance 2020* (London: Routledge, 2020) p. 183.

operating these platforms as well as Syrian fighters for ground combat.[168] Additionally, Turkey could share its expertise and experience with the employment of modern tactics and concepts of operations including reliance on decoys for detecting and striking enemy ground-based air-defense systems, special forces endowed with laser-designators for deep precision strikes, and integration and coordination of different systems such as drones and long-range artillery together.[169]

Armenia was not only the militarily weaker side but also did not receive any significant external support. In contrast to the drone revolution thesis, however, Armenia made little use of drones, and when the balance tilted to its disadvantage, its could not turn to drones to redress the situation on the battlefield. Interestingly, Azerbaijan employed a significant number of drones: however, they were all foreign-made and supplied: the Turkish TB2 *Bayrakta*r UAVs (in undefined number), the Israeli-made intelligence, surveillance and reconnaissance (ISR) drones Hermes-900 (2), Hermes-450 (10), Heron (5), Aerostar (14) and Searcher (5) as well as the Israeli loitering munitions Harop (50), Orbiter 1K (80), Orbiter-3 (10) and SkyStriker (100).[170] Armenia, conversely, deployed a relatively modest fleet of unmanned aerial vehicles consisting of small indigenous systems like the X-55, the HRESH (loitering munition) and the Krunk (15), and Russian-made Orlan-10 reconnaissance UAVs.[171] However, as a weapon of last resort, it turned to ballistic missiles against Azerbaijan: like in the case of Syria, this is paradoxical if we assume that drones are easy, cheap and effective.[172]

[168] Freyton, "Armenia-Azerbaijan War"; Marina Miron and Rod Thorton, "Russia's 'Revenge' after Nagorno-Karabakh: Reprisals in Syria for Turkey's Support of Azerbaijan," *Defence In Depth,* December 7, 2020, https://defenceindepth.co/2020/12/07/russias-revenge-after-nagorno-karabakh-reprisals-in-syria-for-turkeys-support-of-azerbaijan/.
[169] Miron and Thorton, "Russia's 'Revenge' after Nagorno-Karabakh."
[170] See Burak Ege Bekdil, "Azerbaijan to Buy Armed Drones from Turkey", *Defense News*, June 25, 2020, https://www.defensenews.com/unmanned/2020/06/25/azerbaijan-to-buy-armed-drones-from-turkey/
[171] IISS, *The Military Balance 2020*, p. 183; Shaikh and Rumbaugh, *The Air and Missile War in Nagorno-Karabakh*
[172] Shaikh and Rumbaugh, *The Air and Missile War in Nagorno-Karabakh*

Close combat and force employment

Contrary to the premises of the drone revolution thesis, the deployment of drones on the battlefield did not cancel close combat and made traditional force employment elements obsolete.

First, close combat has not disappeared even in Nagorno-Karabakh. Despite the wide employment of ballistic missiles, loitering attack and other precision-guided munitions as well as UAVs, infantry units proved pivotal to hold defensive lines or to advance in the front. Groups of mercenaries and coscripts fought on both sides in WWI-style trenches positioned a few meters away from each other.[173] Turkey deployed Syrian mercenary in support of Azerbaijan and, according to some, this was the real game-changer.[174] These mercenaries, in fact, fighting in coordination with other elements of the force structure, contributed to overwhelm Armenian defensive positions even forcing Russia to intervene diplomatically.[175]

Second, drones did not make traditional force employment obsolete. Azeri forces, for instance, skillfully exploited geography to their advantage. Nagorno-Karabakh is an enclave, in a mountainous region, within Azeri territory. Since radar detection requires a line-of-sight between radar and target, proximity to mountains and other natural or artificial obstacles significantly degrades ground-based air defense systems' effectiveness. Azeri forces exploited the morphology of the terrain to limit or delay their exposure to enemy radar and hence minimize the risk of interception.[176] Azeri forces also proved proficient in mastering tactics aimed at blinding, locating and destroying Armenian air defenses.[177] Similarly, they converted multiple Soviet-era Antonov

[173] Bethan McKernan, "Trench warfare, drones and cowering civilians: on the ground in Nagorno-Karabakh", *The Guardian*, October 13, 2020, https://www.theguardian.com/artanddesign/2020/oct/13/trench-warfare-drones-and-cowering-civilians-on-the-ground-in-nagorno-karabakh.

[174] Miron and Thornton, "Russia's 'revenge' after Nagorno-Karabakh."

[175] According to Miron and Thornton, the Syrian mercenaries fought in the front-line and suffered a high casualty rate. It is estimated that about 143 Syrians were dead by as early as mid-October, see Miron and Thornton, "Russia's 'revenge' after Nagorno-Karabakh."

[176] Kofman and Nersisyan, "The Second Nagorno-Karabakh War".

[177] Ron Synovitz, "Technology, Tactics, And Turkish Advice Lead Azerbaijan To Victory In Nagorno-Karabakh," *Radio Liberty – Radio Free Europe*, November 13, 2020, https://www.rferl.org/a/technology-tactics-and-turkish-advice-lead-azerbaijan-to-victory-in-nagorno-karabakh/30949158.html; Armenia did manage to shoot down some Azerbaijani drones, but only limited in numbers: 1 Aerostar Surveillance UAV, 11 IAI Harop Loitering Munitions, 3 SkyStriker Loitering Munitions, 1 Orbiter 1K Loitering Munition, 2 Bayraktar TB2 UCAVs, 8 Unknown UAVs. Data from Oryx Blog, https://www.oryxspioenkop.com/2020/09/the-fight-for-nagorno-karabakh.html. Despite the advantage of Azerbaijani's drones over Armenian air defense systems, media reported some video of Azeris UAVs

An-2 light aircraft into remotely piloted aircraft and used them as decoys to acquire the location of Armenian air-defense systems.[178] By illuminating these false targets, Armenian radars gave up their position, thus becoming themselves target of Azerbaijan anti-radiation missiles and loitering munitions.[179]

Geography favored Azerbaijan from the beginning: the vicinity to Nagorno-Karabakh entailed limited logistical and infrastructural challenges. However, Azeri forces were able to exploit further the situation by taking control of the Gamish Mountain. This gave them a strategic position over the road connecting the front and rear of Armenia's operation, the cities of Kelbajar and Aghdere.[180] As a result, once Armenia's air defense systems had been neutralized, Azeri drones could easily destroy any target along the road.[181] Azerbaijan also proved effective in integrating special forces into its force structure: endowed with laser-designators for acquiring targets deep inside enemy territory such as arms depots and communication centers, and hence carry precision strikes against them.[182]

While both sides displayed significant deficiencies with modern tactics, operations, maneuvering, and strategy, Armenia performed comparatively worse and could not withstand the costs of this imbalance.[183] The absence of a layered air defense system exposed Armenian forces to enemy fire.[184] However, Armenia also displayed little proficiency with modern tactics and

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downed by Yerevan rockets. See Avet Demourian, "Armenia says it shot down Azerbaijani drone near capital", *CTV News*, October 1, 2020, https://www.ctvnews.ca/world/armenia-says-it-shot-down-azerbaijani-drone-near-capital-1.5128978.

[178] In late August 2020, Baku owned approximately 60 converted An-2s stationed at Yevlakh Airport. See Benjamin Fogel and Andro Mathewson, "The Next Frontier in Drone Warfare? A Soviet-era Crop Duster," *Bulleting of Atomic Scientists,* February 10, 2021, https://thebulletin.org/2021/02/the-next-frontier-in-drone-warfare-a-soviet-era-crop-duster/.

[179] Synovitz, *Technology, Tactics, And Turkish Advice*; Fogel and Mathewson, *The Next Frontier in Drone Warfare?*

[180] Ridvan Bari Urcosta, "Drones in the Nagorno-Karabakh," *Small Wars Journal*, October 23, 2020, https://smallwarsjournal.com/jrnl/art/drones-nagorno-karabakh.

[181] Urcosta, *Drones in the Nagorno-Karabakh*, https://smallwarsjournal.com/jrnl/art/drones-nagorno-karabakh.

[182] Documento su intercettazioni telefoniche su Siria dice qualcosa anche su Nagorno-Karabach. See Technical Appendix.

[183] Armenia managed to take advantage of Azeri deficiencies in tactics and operations as well, but it had only a relatively limited number of drones only for ISR, and so it used largely artillery. The drones in Armenia's inventories were their indigenous drones and, later in the conflict, some of the more sophisticated Russian-made Orlan-10 UAVs. Yet, even the Orlan-10 UAVs had low efficacy and lethality as Azeri forces had already gained a clear air superiority on the contested territory. Kofman and Nersisyan, "The Second Nagorno-Karabakh War."

[184] Kofman and Nersisyan, "The Second Nagorno-Karabakh War, Two Weeks In."

operations, as epitomized by massed movements of troops, in the open, during daylight, and without air defense – which left soldiers, vehicles and platforms exposed to enemy lethality.[185] For instance, for several days after the start of the conflict, Azeri drones kept targeting Armenian troops in non-combat mode or while convoying, which suggests that once the inherent weakness of the Armenian air-defense system became apparent, Armenian troops still implemented insufficient countermeasures and counter-tactics such as dispersion or camouflage to avoid exposure to Azeri fire.[186] Additionally, Armenia located its air-defense systems too forward, in relatively exposed fixed positions and over a mountainous region where air defense is even more difficult. As a result, they were more vulnerable and less effective.[187] For this reason, Armenia suffered a high number of casualties and around a third of its tanks have been destroyed.[188]

Drones were not the silver bullet many suggested. First, while drones did definitively play an important role, they were an important "force multiplier" when employed following proper concepts of operations and close coordination with multiple systems such as manned aircraft, land-based artillery, electronic-warfare systems and radars.[189] Without such infrastructural and operational support, they would have remained vulnerable to air defense systems as was the case in the Libya and Syria. And in fact, during the conflict, "many casualties [we]re still inflicted by armor, artillery, and multiple launch rocket systems."[190]

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[185] Synovitz, *Technology, Tactics, And Turkish Advice*; Kofman and Nersisyan, "The Second Nagorno-Karabakh War, Two Weeks In;" Dixon, "Azerbaijan's drones owned the battlefield in Nagorno-Karabakh — and showed future of warfare."

[186] For example, these videos, originally shared by the Azerbaijan's Ministry of Defense, and shared on twitter by Robert Lee. It shows multiple attacks on fixed and mobile Armenian targets. Rob Lee posts on Twitter: https://twitter.com/RALee85/status/1317499586592858114?s=20; https://twitter.com/RALee85/status/1317507836470059008?s=20.

[187] Kofman and Nersisyan, *The Second Nagorno-Karabakh War*; Shaikh and Rumbaugh, The Air and Missile War in Nagorno-Karabakh. Because of the peculiarities of the Nagorno-Karabakh territory, a partly mountainous U-shaped enclave surrounded by Azerbaijan, locating air-defense systems strategically poses inherent challenges. The most distant point from any of the borders with Azerbaijan is at most 70km.

[188] Dixon, "Azerbaijan's drones owned the battlefield in Nagorno-Karabakh — and showed future of warfare."

[189] Freyton, "Armenia-Azerbaijan War.

[190] Kofman and Nersisyan, *The Second Nagorno-Karabakh War*.

This is why the skeptics assert that "depending on drones, including loitering munitions drones, alone would be a strategic mistake ... Deployment of these systems depends on the mix of warfare systems and how they are leveraged."[191]

Conclusions

In this article, we have investigated the dominant narrative about an ensuing drone-driven revolution in military affairs. To understand the role of drone in air warfare, we have adapted Biddle's modern system of force employment to develop a theory of military effectiveness in air warfare. We have argued that starting from the 1960s, a "second firepower revolution" has led to dramatic improvements in detection, communication, precision, and destruction, making air warfare extremely lethal. Such lethality, in turn, has led to a hider-seeker competition between air forces and air defenses. Actors that are not capable of adopting the tactics, techniques, procedures, technologies and capabilities necessary to limit exposure to enemy fire while successfully detecting and targeting the enemy will suffer severe consequences. In the context of this modern system of force employment in air warfare, we have identified three observable expectations that are in direct contrast with the conventional wisdom on the drone revolution, and that are linked with offensive advantage, levelling effect and close combat (summarized in Table 1). We have then tested these observables expectations on three recent conflicts which saw extensive employment of drones: the civil wars in Libya and Syria as well as the 2020 "44 days war" over Nagorno-Karabakh.

[191] Freyton, *Armenia-Azerbaijan War*.

Table 1: Drone Warfare: Summary of Expected Outcome

	Expectations according to the Drone revolution thesis	Expectations according to the modern system of force employment
Offensive Advantage	Low attrition rates / Drones able to overcome existing air-defense systems /	High-attrition rate / Variation with presence and capabilities of air-defense systems
Levelling Effect	Drones are widely available and employed on the battlefield / Weaker actors eventually able to ramp-up production	Drones are not widely available / They are more extensively and effectively used by the stronger side
Close Combat	Less salient in conflict / Exclusive reliance on long-range precision strikes	Still salient in conflict / Key role of combat skills and proficiency in traditional force employment

Our empirical analysis shows that drones are not a transformative technology that has the potential to tilt the military balance towards the offense, level the playing field, or to make close combat obsolete. Drones could not operate with impunity in these conflicts, as they are vulnerable to electronic warfare and air defense system, and for this reason they did not shift military balance towards the offense. Moreover, because of the support that they require from other military platforms and conventional capabilities, drones have not levelled the playing field: drones did not strengthen poor states or non-state actors. In fact, those that managed to operate drones most successfully were either powerful states or states receiving infrastructural and operational support by regional powers. Finally, UAVs have not cancelled close combat, as the conquest and control of territory, especially in areas with natural opportunities for cover and concealment, remain a prerogative of ground troops. In the end, we conclude, drones can be effective when they are integrated with other multi-layered and conventional systems (artillery, manned aircraft, radar, ground-based and aerial-based electronic warfare capabilities and ground units) and are operated by skilled and proficient. To be sure, the evidence presented in this article is not definitive. The conflicts under investigation are very recent and new empirical works may supplement the preliminary analysis we have carried out. Yet, our work calls for more attention to contextualize the role of drones in what we call the modern system of force employment in air warfare.

Theoretically and empirically, assessing and contextualizing the employment of drones through the the modern system of force employment framework is a fundamental exercise to avoid indulging in premature and possibly erroneous scholarly interpretations or policy prescriptions. We argue that the modern system of force employment in air warfare is critical to gauge the impact of emerging security technologies (drone swarms, artificial intelligence, hypersonic weapons, quantum computing and lethal autonomous weapons) on the battlefield. Contrary to some alarmist speculations, drones are not lowering the entry barriers to wage war, and they have not made traditional force structure, defense policies and reliance on sophisticated military platforms obsolete. Moreover, our framework allows to highlight some factors that are often underestimated in the public and academic debate, such as the fundamental role of skilled and proficient personnel as well as of electronic warfare and air defense systems. This is something that regional powers as well as great powers should keep in mind, for example if their local allies end up being targeted by drones' attacks. The deployment of air defense systems and electronic warfare systems, together with the personnel employing them, can significantly degrade and possibly halt a military offensive based on current generation unmanned aerial systems.