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Game-changers:
Implications of the Russo-Ukraine War for the Future of Ground Warfare

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A year into the most recent Russian invasion of Ukraine, defense analysts are split on whether the conflict manifests major change in the character of ground warfare or merely the introduction of technological upgrades that have little transformative impact. It is the purpose of this paper to inform this debate.

To understand the significance of this war for the future of ground combat, the paper will examine what is known publicly about the performance of Russian and Ukrainian forces at the tactical and operational levels. It will start by examining the ground force structures of the opponents. Then, the paper will identify verities—the dimensions of their performance which affirm continuities in the nature of ground combat—and contrast them with game changers—the attributes of forces' performance which are signaling transformational change in how ground combat is successfully prosecuted. The paper concludes with a discussion of how the Ukraine game changers should shape the strategies, operating concepts, programs, and plans of US, allied and partner militaries.

Ground Force Structures

To begin, it is important to acknowledge that the bulk of each force's formations are armed with decades-old equipment and tactics. At the start of the conflict, over 90 percent of each forces' equipment—aircraft, tanks, armored personnel carriers, logistics vehicles, and artillery—was developed, and often produced, in the twentieth century; each side's personnel trained accordingly. To understand what is changing, therefore, it is essential to focus on the impact of the small percentage of each force that is modern.

Russian Ground Forces.

Prior to the war, many observers claimed that the battalion tactical groups (BTGs) proved that the new Russian Army was innovative. Yet even the BTGs were the product of experiments conducted in the 1980s. Observers failed to note that the BTG commander was burdened with the control of eleven organic units and up to fifteen additional attached direct support

Destroyed Soviet-era Russian tank is seen amid Russia's invasion of Ukraine, taken near the Kyiv Oblast. Tanks like this make up a bulk of Russian and Ukrainian armored forces. Credit: Alex Fedorenko, https://unsplash.com/photos/zBMKUdPAKmk.

units.[1] Failure to innovate was not Russia's only error. However, its failures at the strategic, operational, and tactical levels have been well covered elsewhere.[2]

The failure of their initial offensive forced the Russians to fall back on their traditional twentieth-century regimental and brigade-level organizations for the rest of 2022. By early 2023, however, Russia started reorganizing its primary ground combat units into assault detachments.[3] These smaller detachments are combined arms organizations, but because of Russia's heavy personnel and equipment losses, they have much less firepower than BTGs while maintaining an unwieldy span of control for the assault detachment (battalion) and company commanders.

Ukrainian Ground Forces.

At the outset of the war, Ukrainian forces were also equipped primarily with twentieth-century equipment but were transitioning from Soviet operational concepts to Western ones. Further, Ukrainian forces' leadership understood the special utility of the small portion of its forces that were developed in the twenty-first century—and exploited it successfully. Ukrainian commanders have shown remarkable ingenuity and flexibility across the battlespace. For instance, in the opening days, they

1 Lester W. Grau and Charles K. Bartles, "Getting to Know the Russian Battalion Tactical Group," Royal United Services Institute (RUSI), April 14, 2022, https://rusi.org/explore-our-research/publications/commentary/getting-know-russian-battalion-tactical-group.

2 Seth G. Jones, "Russia's Ill-Fated Invasion of Ukraine: Lessons in Modern Warfare," Center for Strategic and International Studies (CSIS), June 1, 2022; Dara Massicot, "What Russia Got Wrong," *Foreign Affairs*, March/April 2023, https://www.foreignaffairs.com/ukraine/what-russia-got-wrong-moscow-failures-in-ukraine-dara-massicot.

3 Sebastian Roplin, "Captured Manual Reveals Russia's New 'Assault Detachment' Doctrine," *Forbes*, February 28, 2023, https://www.forbes.com/sites/sebastienroblin/2023/02/28/captured-manual-reveals-russias-new-assault-detachment-doctrine/?sh=5d77bf7e4bb3.

Soldiers of Dnipro Brigade of The National Guard of Ukraine showing a downed Russian Grifon 12 UAV in Donetsk Oblast. A Kvertus drone jammer is also shown. October 23, 2022. Credit: National Guard of Ukraine / ngu.gov.ua. https://commons.wikimedia.org/wiki/File:UA_NGU_downed_Russian_Grifon_12_01.jpg.

paired special forces soldiers armed with man-portable anti-tank weapons with local reserves riding four-wheeled off-road vehicles.[4] This unique pairing hit Russian logistics elements deep behind the initial assault forces. In the year since the start of the war, Ukrainian forces have continued to show ingenuity in mixing the old with the new.

Verities

The Russo-Ukraine war has reinforced important continuities in military operations.

- **Preparation:** As ever, forces that have employed sound planning, honest war-gaming, and the availability of alternative courses of action are enjoying greater success on the battlefield.
- **Flexibility:** A primary difference between the two forces has been the Ukrainian armed forces' adaptability to tactical surprise, compared to the Russian forces' rigidity.
- **Logistics:** Logistics consistently have restricted both sides' tactical actions. Russia planned to win quickly. When it failed to do so, entire units ran out of fuel and abandoned their vehicles. Russia failed to effectively deploy supporting logistics units.[5] For its part, Ukraine lacked sufficient ammunition reserves and, even with outside support, has struggled to provide ammunition throughout the conflict.
- **Industrial base:** Russia anticipated a short war. Senior Ukrainian officials publicly downplayed the prospects of a Russian attack. Neither country mobilized its industrial base before the war.
- **Fires:** Both armies remain equipped mostly with twentieth-century weapons, meaning that firepower—

4 Michael G. Anderson, "How Ukraine's Roving Teams of Light Infantry Helped Win the Battle of Sumy," Modern War Institute, August 17, 2022, https://mwi.usma.edu/how-ukraines-roving-teams-of-light-infantry-helped-win-the-battle-of-sumy-lessons-for-the-us-army/; Dan Parsons, "Ukrainian Battle Buggies Are Out to Kill Russian Tanks," *WarZone*, April 28, 2022, https://www.thedrive.com/the-war-zone/ukrainian-battle-buggies-are-out-to-kill-russian-tanks.

5 Grau and Bartles, "Getting to Know the Russian Battalion Tactical Group."

Ukrainian troops conducting exercises “Rubizh - 2016” at the “Divychky” training ground in the Kyiv region using a Soviet-era 2S7 Pion. These platforms form the backbone of Ukraine’s artillery forces. Credit: Ministry of Defense of Ukraine. https://flickr.com/photos/140624011@N02/30569568452.

particularly artillery—has been critical. Cannon artillery has played a central role in this war, with about two million rounds fired. Russian mass use of artillery compensated for ineffective maneuver forces. Ukraine more effectively used its comparatively limited artillery by exploiting superior intelligence and command and control. Ukrainian forces adeptly employed long-range High Mobility Artillery Rocket Systems (HIMARS) to dramatically damage Russian ammunition resupply. Regardless, neither army’s employment of fires has been decisive in the conduct of the war.

- **Counterfires:** Both sides have dedicated significant assets to counterfire. Each has active counterbattery radars to include difficult-to-detect passive, acoustic sensors ranging from the Russian *Penicillin* system to Ukrainian innovative efforts to develop cheap drones with acoustic systems.[6] Both sides have conducted counterbattery missions with drones. Effective counterbattery systems will remain a critical element in every major fight.
- **Electronic warfare (EW):** Modern militaries require access to the electromagnetic spectrum for all operations.[7] Russia has long recognized this fact and invested heavily in EW.[8] Still, Russian forces failed to conduct effective EW during the war’s opening phase, and unencrypted Russian communications provided a wealth of intelligence for Ukraine. It was only after withdrawing eastward and deploying three of its five EW brigades to the theater that Russian

6 Stephen Bryen, “A Drone Cure for Russian’s Artillery-killing ‘Penicillin,’” *Asia Times,* January 20, 2023, https://asiatimes.com/2023/01/a-drone-cure-for-russias-artillery-killing-penicillin/.

7 The United States, however, does not recognize the electromagnetic spectrum as a domain of war.

8 John Christianson, “Fighting and Winning in the Electromagnetic Spectrum,” *War on the Rocks*, December 5, 2022, https://warontherocks.com/2022/12/fighting-and-winning-in-the-electromagnetic-spectrum/.

forces effectively used EW.[9] As the lines stabilized in the east, Russian EW has been credited with most of the kills versus Ukrainian drones.[10] As the impact of EW became clear, both sides scrambled to protect their own systems while denying enemy use of the spectrum.

- **Cyber Warfare:** Another new technology that was expected to have a major impact, cyber, has surprised mostly by its overall ineffectiveness. As US Deputy Assistant Secretary of Defense for Cyber Policy Mieke Eoyang has noted, cyber "did not have the strategic impact they [the Russians] wanted."[11] Despite launching the largest number of data-wiping malware attacks ever, the Russians have been relatively ineffective.[12] Most observers attribute Ukraine's preparedness to the fact that Ukraine had been defending against Russian cyberattacks for years. So far, Ukraine, assisted by both Western governments and commercial firms, has demonstrated that collective cyber defense has "proven stronger than offensive cyber capabilities."[13] Future conflicts will certainly involve cyber operations, so national defense requires sustained cyber defense, but cyber offense has not been a game changer so far.
- **Information Warfare:** The Ukrainians' master class in information warfare has only reinforced the time-honored precept of controlling the narrative of conflict. From Ukrainian President Volodymyr Zelenskyy's statement, "I need ammunition not a ride," to squad-level TikTok videos, the message has been well articulated and consistent: Ukraine will fight for its freedom against a brutal Russian regime. Getting the right *external* message out fast has been a key element in sustaining Western support for sanctions on Russia as well as providing military and economic aid to Ukraine. So too has Russia succeeded in controlling the narrative of the conflict circulating inside its borders and around the Global South. And while new technologies have not fundamentally changed information warfare, the availability of commercial satellite imagery and satellite data has made it more difficult for disinformation campaigns to be successful. Maxar and other satellite data providers fundamentally changed the framing of the conflict, effectively disproving Russia's justification for the war and exposing its forces' most atrocious actions.[14]

Game-changers

As noted, both forces are essentially twentieth-century organizations. Yet each has a small percentage of weapons and operating concepts developed in the twenty-first century that are leading indicators of how ground warfare is changing to favor the defense.[15]

Today, the Ukrainians have combined new technologies to develop three capabilities that are changing the game of land warfare by dramatically improving the power of the defense. First, Ukraine has developed truly connected, high-speed command and control. Second, Ukraine has access to near-persistent surveillance of the battlespace. Third, Ukraine's skilled use of precision artillery, drones, and loitering munitions demonstrated how its smaller, lighter forces could defeat Russia's offensive.

- **Integrated Command and Control:** Ukraine's most dramatic improvement in its combat capabilities is its integration of diverse civilian systems into a coherent and highly effective command-and-control system. After viewing the system in operation, Gen. Mark A. Milley, chairman of the US Joint Chiefs of Staff, stated:

9 Bryan Clark, "The Fall and Rise of Russian Electronic Warfare," *IEEE Spectrum*, Institute of Electrical and Electronics Engineers, July 30, 2022, https://spectrum.ieee.org/the-fall-and-rise-of-russian-electronic-warfare.

10 Mykhaylo Zabrodskyi, Jack Watling, Oleksandr V. Danylyuk, and Nick Reynolds, "Preliminary Lessons in Conventional Warfighting from Russia's Invasion of Ukraine: February–July 2022," RUSI, November 30, 2022, https://static.rusi.org/359-SR-Ukraine-Preliminary-Lessons-Feb-July-2022-web-final.pdf.

11 Jasper Gill, "DoD Must 'Think Very Differently' About Armed Conflict, Cyber in the Light of Ukraine War: Official," *Real Clear Defense*, November 17, 2022, https://www.realcleardefense.com/2022/11/17/dod_must_think_very_differently_about_cyber_in_armed_conflict_865423.html.

12 Andy Greenbert, "Ukraine Suffered More Data-Wiping Malware Last Year Than Anywhere, Ever," *Wired*, February 22, 2023, https://www.wired.com/story/ukraine-russia-wiper-malware/.

13 Nick Beecroft, "Evaluating the International Support to Ukrainian Cyber Defense," Carnegie Endowment for International Peace, November 3, 2022, https://carnegieendowment.org/2022/11/03/evaluating-international-support-to-ukrainian-cyber-defense-pub-88322.

14 The Maxar News Bureau has released satellite imagery to global media countering the Russian narrative that they were pulling their troops back from the border before the start of the invasion, substantiating the bombing of the theater in Mariupol in March of 2021, and documenting which Russian military unit is most likely responsible for the killing of civilians in Bucha.

15 In fact, the tactical level offense-defense balance has shifted throughout history. In 1918, the German *Sturmtruppen* and the British tanks represented only a fraction of their respective armies, but astute observers gleaned insights on the future character of warfare from these units. They understood that combining *Sturmtruppen* tactics with evolving armor, air, and communications systems could restore offense advantage to the tactical battlefield.

A Ukrainian soldier setting up a Starlink terminal. The Starlink satellite network has been leveraged significantly by Ukrainian troops in combination with traditional tactics and drone technology. Credit: Support Forces of Ukraine Command / Mil.gov.ua. https://commons.wikimedia.org/wiki/File:UA_Support_Forces_Starlink_01.jpg.

"We are witnessing the ways wars will be fought, and won, for years to come."[16]

Communication systems: Ukrainian command and control did not begin well. As the invasion started, Russia conducted a successful cyberattack on the ViaSat commercial satellite system that was a backbone of Ukrainian communications.[17] Ukraine responded within days by deploying thousands of Starlink terminals that provided a much more robust nationwide communications system. Three key characteristics explain the Starlink constellation's resilience. First, the sheer number of satellites—over three thousand currently operational—makes it extremely difficult to destroy the network through kinetic attack. Second, the downlink stations also are numerous—over thirty thousand were in service or on-order at the end of last year—and small—about the size of a pizza box—so that they are easy to move and camouflage.[18] Finally, the system uses sophisticated electronics to create the tight beams necessary to follow the satellites in their fast transit across the sky. The tight beam and low latency inherent in the low-Earth orbit make the signal very difficult to jam. In addition, the constellation provides a much higher throughput capacity, which gives small tactical units and even individuals the bandwidth previously reserved for major commands.[19]

16 David Ignatius, "How the Algorithm Tipped the Balance in Ukraine," *Washington Post*, December 20, 2022, https://www.washingtonpost.com/opinions/2022/12/19/palantir-algorithm-data-ukraine-war/.

17 Patrick Howell O'Neill, "Russia Hacked an American Satellite Company One Hour Before the Ukraine Invasion," *MIT Technology Review*, May 10, 2022, https://www.technologyreview.com/2022/05/10/1051973/russia-hack-viasat-satellite-ukraine-invasion/.

18 "Minister: Ukraine to Receive over 10,000 Starlink Systems in Coming Months," *Kyiv Independent*, December 20, 2022, https://kyivindependent.com/news-feed/minister-ukraine-to-receive-over-10-000-starlink-systems-in-coming-months.

19 "Starlink's Performance in Ukraine has Ignited a New Space Race," *Economist*, January 5, 2023, https://www.economist.com/leaders/2023/01/05/starlinks-performance-in-ukraine-has-ignited-a-new-space-race.

Coding: While the Starlink constellation was critical, only Ukraine's tech-savvy human capital made the quick adaptation possible. The key enabler was the large pool of talented Ukrainian information technology personnel that quickly wrote the code that tied the prewar *Diya* national electronic government system to both civilian and military users through the Starlink constellation.

> In the first weeks of the full-scale war, the Ministry of Digital team created the chatbot eVerog. Everyone with a smartphone can share photos of enemy equipment, report collaborators or mines. Almost half a million Ukrainians have used the chatbot for the entire time.[20]

Still, Ukraine continued to refine its system with the creation of what is being called Delta.

> Delta provides a comprehensive understanding of the battle space in real time, integrates information about the enemy from various sensors and sources, including—intelligence, on a digital map, does not require additional settings, and can work on any device—laptop, tablet or even on a mobile phone. Roughly speaking, Delta is . . . a modern real-time command map and troop control center.[21]

Delta also ties into the NATO system, which draws data from both commercial and classified government systems. Delta then uses artificial intelligence (AI) developed by Palantir to analyze and speed the data to the user. While the NATO system provides crucial inputs, only Ukraine has employed a digital command-and-control system that allows it to integrate the intelligence provided by satellites, drones, and military systems. In essence, Ukrainian coders have created for ground commanders a field-expedient, inexpensive version of the Pentagon's ambitious Joint All-Domain Command and Control (JADC2) system.

Ukrainians claim to have a coder assigned to each battalion-sized unit. While most nations will not be able to fill such a personnel requirement, reports from this year's World Economic Forum indicate technology may provide a substitute.

> The AI development company DeepMind created an algorithm . . . AlphaCode can beat 72 percent of human coders in average competitions and recently solved about 30 percent of the coding problems in a highly complex coding competition against humans. . . . It is unlikely that AI will take over programming completely, but it will cut the number of humans needed to code dramatically.[22]

This software also assists commanders in prioritizing targets and developing attack options, which are transmitted quickly to artillery, missile, and drone batteries for engagement. Of note is the creation of a so-called "Uber for artillery."[23] Citizens or soldiers can report Russian activity via numerous paths to include cells phones. The Uber-like connectivity then allows artillery commanders to see the targets and decide immediately if they wish to engage. Systems like this will enable commanders to coordinate combined arms attacks across all domains informed by many sources and sensors.

- **Pervasive Surveillance:** Ukrainian forces have gained access to pervasive surveillance due primarily to their employment of commercial satellites and drones.

  Satellites: By early March 2022, five commercial firms were sharing day and night satellite imagery that assisted Ukraine in tracking Russian forces. By December, Ukraine could tap into the "roughly 40 commercial satellites a day [that] pass over the area in a 24-hour period."[24]

  Ukraine—and other national governments—can tap into more than a dozen companies which are competing to provide ever faster, more precise

20 "The Year of Indomitability of the Ministry of Digital: Military Services in Diya and Other Top 100 achievements of the Ministry," Diya (Ukrainian government portal), December 27, 2022, https://diia.gov.ua/news/rik-nezlamnosti-mincifri-vijskovi-poslugi-v-diyi-ta-inshi-top-100-dosyagnen-ministerstva.

21 Oleg Danylov, "The Unique Ukrainian Situational Awareness System Delta was Presented at the Annual NATO event," *Mehza Media* (technology information site), October 28, 2022, https://mezha.media/en/2022/10/28/the-unique-ukrainian-situational-awareness-system-delta-was-presented-at-the-annual-nato-event/.

22 "What Were the Key AI Developments in 2022?" World Economic Forum, January 20, 2023, https://www.weforum.org/agenda/2023/01/davos23-biggest-ai-developments-how-to-use-them/.

23 Mark Bruno, "'Uber For Artillery'—What is Ukraine's GIS Arta System?," *Moloch* (journalism project), August 24, 2022, https://themoloch.com/conflict/uber-for-artillery-what-is-ukraines-gis-arta-system/.

24 Ignatius, "How the Algorithm Tipped the Balance in Ukraine."

Satellite image of Russian fortifications in Kherson Oblast on November 15, 2022 featuring anti-tank obstacles and a network of trenches. Credit: Satellite image ©2023 Maxar Technologies. https://maxar.mediavalet.com/galleries/61be2dbb-80e7-401f-8a32-6c9e72bb894c_495109b2-ba67-4a5d-b266-0d78a5a93329-ExternalUser/91fa8d0b-6043-4dd1-a794-ee3f344c14c3.

multispectral products to commercial customers and real-time transparency to a global audience. Maxar, for example, has been providing imagery to the US government for over two decades; others for the past few years.[25] To see through darkness, cloud cover, and light foliage, several companies now offer interpreted synthetic aperture radar (SAR) imagery of any point on Earth, on demand at least every six hours.[26] By mid-2023, a satellite formation will be able to locate a specific radio frequency signature with an accuracy of 3 kilometers every twenty minutes.[27] These are just a few of the dozens of commercial offerings which, by 2030, are projected to have 2,600 Earth-observation satellites serving a market valued at more than $76 billion.[28]

As a result, Earth observation from space-based visual, infrared, radar, and electromagnetic sensors is available virtually continuously. As noted, commercial satellite companies target the commercial market, so they emphasize customer-oriented, automated processes from request to delivery of an interpreted product. While these firms can provide raw imagery or data, the companies also have developed change-detection software to facilitate the provision of finished intelligence products.

25 "Maxar Awarded G-EGD Contract Renewal to Provide Mission-Ready Satellite Imagery for U.S. government," *Investing News Network*, September 20, 2022, https://investingnews.com/maxar-awarded-g-egd-contract-renewal-to-provide-mission-ready-satellite-imagery-for-u-s-government/.

26 "Capella SAR-X," eoPortal (with support of European Space Agency), https://directory.eoportal.org/web/eoportal/satellite-missions/c-missions/capella-x-sar.

27 Aria Alamalhodaei, "HawkEye 360 Raises $145M to Scale Space-Based Radio Frequency Data and Analytics," *TechCrunch*, November 8, 2021, https://techcrunch.com/2021/11/08/hawkeye-360-raises-145m-to-scale-space-based-radio-frequency-data-and-analytics/.

28 "Manufacturing Revenues for Earth Observation to Grow to $76.1 Billion by 2030, Bolstered by Existing Government Programs, New Entrants and Diversified Commercial Constellations," Press Release, Euroconsult, January 13, 2022, https://www.euroconsult-ec.com/press-release/manufacturing-revenues-for-earth-observation-to-grow-to-76-1-billion-by-2030-bolstered-by-existing-government-programs-new-entrants-and-diversified-commercial-constellations/.

Russian drone shot down over Donetsk Oblast on 5 April 2022 by the Kramatorsk Border Detachment of The State Border Guard Service of Ukraine. Drones like these are routinely conducting air reconnaissance. Credit: State Border Guard Service of Ukraine / Dpsu.gov.ua. https://commons.wikimedia.org/wiki/File:Russian_drone_shot_over_Donetsk_Oblast_(5_April_2022)_02.jpg.

Drones: An exponential increase in the number of drones in Ukraine is also the result of global commercial initiatives. Both commercial firms and governments are developing families of ever more capable surveillance drones. These drones range from small, hand-launched platforms to aircraft with wingspans over one hundred feet. Like their satellite complements, these companies also have developed multispectral, SAR, and electro-magnetic sensors (EMS) for every size of drone.

At the small end, hundreds of videos from Ukraine show commercial quadcopters and octocopters dropping modified anti-armor weapons and grenades on Russian forces. Ukraine has as many as "500 drones in the air for a relatively standard military operation."[29] But their most important function has been to provide critical intelligence and artillery spotting for tactical units in contact with enemy forces.

The increasing capabilities of commercial drones are changing the game of how militaries will use this technology. For example, major corporations are aggressively pursuing drone package delivery. The requirements for delivery are essentially the same as for military platforms—vertical takeoff and landing (VTOL), Global Positioning System (GPS)-independent navigation (to fly in urban canyons), electronic hardening (to fly near airfields and radio towers), reliability, and low cost with ever increasing endurance and payloads. Commercial surveillance drones also make use of multispectral imagery (crop surveillance, pipeline leakage), high-resolution imagery (wind generator or bridge inspections), and even SAR. An increasing range of long-endurance, commercial drones carrying commercial surveillance payloads such as these will allow even smaller states access to affordable intelligence, surveillance, and reconnaissance (ISR) and attack.

29 Mark Bowden, "The Tiny and Nightmarishly Efficient Future of Drone Warfare," *Atlantic*, November 22, 2022, https://www.theatlantic.com/technology/archive/2022/11/russia-ukraine-war-drones-future-of-warfare/672241/.

The Russo-Ukraine conflict is not only demonstrating the value of drones but also the requirement for very large numbers of them. The Royal United Services Institute (RUSI) reports that quadcopters survive an average of only three missions, and fixed-wing drones survive for only six missions.[30] To sustain the roughly five hundred drones that the Ukrainians use to support a major operation requires a very large number of surveillance drones.

To meet this demand, advanced manufacturing techniques are in development:

> Automated factories, robotics, and artificial intelligence can be combined to dramatically reduce the cost of these emerging autonomous systems. In 2014, an aeronautics professor designed and 3D-printed a drone. By adding a small electric motor, two batteries, and a cell phone, he created a hand-launched, autonomous drone with a range of 50 km.
>
> Once the design was refined, the production process took about 28 hours. Today's 3D printers are over 100 times faster. A plant with 100 modern 3D printers could produce 10,000 of these drones per day. By incorporating AI and robotics, the final assembly could be automated. Thus, drone swarms of thousands of autonomous hunters are possible today.[31]

Augmenting the satellites and drones is the proliferation of open-source intelligence (OSINT), which has been a valuable source of intelligence since the beginning of the conflict. But the information revolution means the volume of open-source information has exploded and created new vulnerabilities for military forces.

> For armies seeking to maintain operational security, this profusion of data is a nightmare. . . . In December a Russian volunteer posted photos on vk [a popular Russian social media platform] of forces encamped in a country club in Sahy, an occupied part of Kherson province. His post included a geo-tag of the exact location. Ukrainian missiles later struck it, after which the volunteer posted yet again. This time he uploaded a video showing the extent of the destruction, in effect giving Ukraine a damage assessment from on the ground.[32]

The bottom line was well expressed by RUSI researchers who noted that, in this era of persistent surveillance, ground forces must "disperse, dig deep, or move fast."[33]

- **Mass, Precise Fires:** The current conflict has highlighted the value of having large numbers of widely-deployed precision weapons. From man-portable anti-tank weapons to artillery to strike drones, widely deployed precision weapons have allowed small units to inflict heavy damage on their opponents while actually reducing the logistics burden of moving large quantities of ammunition forward.

  Man-portable anti-tank weapons: Early in the conflict, the Ukrainians had remarkable success using a variety of man-portable anti-tank weapons to blunt Russian attacks. While the Javelin received most of the publicity, it was augmented by Stugna-P anti-tank guided missiles, Next-generation Light Anti-tank Weapons (NLAWs), Carl Gustav recoilless rifles, and rocket-propelled grenades (RPGs). Some commentators have stated these weapons could have been neutralized by effective combined-arms tactics, in particular, the effective use of infantry to support the armor.[34] While this may have been true in the past, the extended range of new systems makes infantry

30 Justin Bronk, Nick Reynolds, and Jack Watling, "The Russian Air War and Ukrainian Requirements for Air Defence," RUSI, November 7, 2022, https://rusi.org/explore-our-research/publications/special-resources/russian-air-war-and-ukrainian-requirements-air-defence.

31 T. X. Hammes, "Defence Dominance: Advantage for Small States," S. Rajaratnam School of International Studies, Nanyang Technological University, *RSIS Commentary* (platform), no. 151 (October 19, 2021), https://www.rsis.edu.sg/wp-content/uploads/2021/10/CO21151.pdf.

32 "Open-Source Intelligence is Piercing the Fog of War in Ukraine," *Economist*, January 13, 2023, https://www.economist.com/interactive/international/2023/01/13/open-source-intelligence-is-piercing-the-fog-of-war-in-ukraine/.

33 Zabrodskyi et al., "Preliminary Lessons in Conventional Warfighting."

34 Rob Lee, "The Tank is not Obsolete, and Other Observations About the Future of Combat," *War on the Rocks*, September 6, 2022, https://warontherocks.com/2022/09/the-tank-is-not-obsolete-and-other-observations-about-the-future-of-combat/.

Aftermath of a Russian tank struck by a Stugna-P anti-tank guided missile operated by Ukraine's 80th Air Assault Brigade. Ukraine April 6, 2022. Credit: armyinform.com.ua. https://commons.wikimedia.org/wiki/File:Russian_tank_destroyed_by_Ukrainian_ATGM_Apr_3_2022.jpg.

screens infeasible. To cover the advance against an NLAW's 800 meter range, the infantry would have to form a perimeter of 5,000 meters around the armor. Against a Javelin's 4,000 meter range, the infantry would have to create a perimeter of 25,000 meters. While the Javelin's high cost ($175,000 dollars per missile) will limit the number present on the battlefield, the much lower cost and high versatility of the NLAWs ($33,000), Carl Gustav M4s ($500 to $3,000 per round), and RPG-7s ($2,500), virtually ensure they will be present in large numbers. Since a modern tank can cost as much as nine million dollars, these precision weapons are especially effective instruments of cost-imposition strategies.

Artillery: Numerous images reveal open fields with thousands of artillery impact craters where a round did not hit anything of value. In contrast, precision artillery has demonstrated the ability to destroy targets from individual vehicles to ammunition storage sites with a single round. This capability minimizes the exposure of the firing unit to counterbattery fire and exponentially reduces the logistics burden of ammunition resupply. Unfortunately, while the United States shipped over one million rounds of 155 millimeter artillery, only five thousand were precision Excalibur rounds, which have a circular error probable of four meters.[35] Although only a fraction of the munitions expended by either side are precision weapons, the outsized impact of these rounds when directed by surveillance drones provides a glimpse into how the proliferation of precision weapons and drones will alter the battlespace.

In addition to demonstrating the outsized impact of precision, the war also indicates the need for transformational artillery systems to exhibit high rates of fire, cross-country mobility, reduced or simplified maintenance, and long tube life. Long range allows artillery to be physically dispersed and still mass fires when needed. The Russo-Ukraine war has brutally demonstrated the need for artillery to be mobile and capable of lone-gun or section operations to minimize the effects of counterbattery fire.

Strike drones and loitering munitions: The Nagorno-Karabakh conflict first demonstrated the outsized impact that strike drones can have in armed hostilities.[36] Of the 743 pieces of Armenian equipment destroyed in that conflict, 563 were certainly destroyed by drones, 39 certainly not destroyed by drones, and the remaining 141 were unknown.[37] So too are drones and loitering munitions proving deadly in Ukraine. Early on, the Ukrainians were quick to publicize the success of the Bayraktar TB-2 drones as they destroyed dozens of Russian vehicles. But as usual in warfare, the adversary responded. Russia adjusted its air defense systems, greatly reducing the effectiveness of these drones. Since then, both sides have exploited the potential of both military and civilian drones by employing thousands. "For Ukraine, airpower is largely taking the form of drones, a first for a large nation."[38]

35 Seth Jones, "Empty Bins in a Wartime Environment," CSIS, January 2023, https://csis-website-prod.s3.amazonaws.com/s3fs-public/2023-01/230119_Jones_Empty_Bins.pdf.

36 John Antal, *7 Seconds to Die: A Military Analysis of the Second Nagorno-Karabakh War and the Future of Warfighting* (Havertown, PA: Casement Publishers, 2022).

37 Eado Hecht, "Drones in the Nagorno-Karabakh War: Analyzing the Data," *Military Strategy Magazine* 7, no. 4, (Winter 2022): 31-37, https://www.militarystrategymagazine.com/article/drones-in-the-nagorno-karabakh-war-analyzing-the-data/.

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

A TU-141 being used as a target for Ukrainian anti-air forces during the "United Efforts 2021" exercise in Yahorlyk. Now these systems are reportedly being used as long-range cruise missiles to attack Russian airbases. Credit: Ukraine Air Force / Mil.gov.ua. https://commons.wikimedia.org/wiki/File:UA_anti-air_training_2021_TU-141_(1).jpg.

The vast majority of Ukraine's drones are open-market commercial products that have been purchased and assembled by volunteers. These systems are then sent forward to Ukrainian units for deployment. To supplement commercial drones, *Forbes* reports that creative engineers are even building them on "a simple plastic frame with a Foxeer Razer video camera, costing about $14, a Diatone Mamba MK4 flight controller ($44) and a Lollipop 4 antenna ($20)."[39] These homemade drones are fixed rather than rotary wing and can be equipped with handmade anti-personnel bombs that are more powerful than the standard grenades dropped by the quadcopters.

Ukraine's employment of drones also is benefiting from innovations and adaptation in their employment. Ukraine's use of Soviet-era Tu-141 and Tu-143 jet-powered reconnaissance drones to attack airfields deep inside Russia provides a glimpse of the threat the proliferation of drones and cruise missiles present to crewed aviation.[40] Crewed fixed-wing aviation requires airfields and major logistic support bases. In an era of persistent surveillance, they will be targeted. In addition, new drones outrange many, if not most, crewed fighter/bombers. Orders of magnitude cheaper than crewed aircraft, these missiles and drones provide even small states with the ability to strike airbases and parked aircraft.

As the effectiveness of drones became obvious in this conflict, both sides scrambled to develop effective air defenses. On January 2, a Ukrainian spokesman stated that Ukraine had shot down all forty-five of the Shahed drones Russia launched on January 1, as

39 David Hambling, "Bargain Basement Bombers: Ukraine's Homemade Drones Hit Russian Forces," *Forbes*, January 24, 2023, https://www.forbes.com/sites/davidhambling/2023/01/24/bargain-basement-bombers--ukraines-homemade-drones-hit-russian-forces/.

40 Howard Altman, "Ukraine Strikes Back at Bomber Base Deep Inside Russia," *Warzone*, December 26, 2022, https://www.thedrive.com/the-war-zone/ukraine-strikes-back-at-bomber-base-deep-inside-russia.

well as forty-four more on January 2.[41] But the fact that these drones cost as little as $20,000 dollars, yet have an Iranian-claimed range of 1,500 kilometers, gives an indication that large numbers of cheap drones will attack targets deep inside enemy territory in future conflicts.[42] Ukrainian intelligence reports the Kremlin has ordered an additional twenty-four hundred Iranian drones.[43]

For its part, an Ukrainian intelligence unit is appealing for donations to buy one thousand kamikaze drones, a plea that has already provided it fourteen hundred drones.[44] Still, an adviser to Ukraine's minister of internal affairs insists that Ukraine will win faster if it has "tens of thousands, hundreds of thousands of reconnaissance and combat drones."[45] By applying advanced manufacturing techniques to the existing 3D printing processes used to create fixed-wing drones, these numbers may be achievable.

As important as precisions fires already have been to defending Ukraine, it is important to note that those employed represent only a small selection of the precision munitions being developed worldwide. For instance, the US-produced Ground Launched Small Diameter Bomb's 250-pound warhead can be delivered by rocket to a range of almost one hundred miles. With a warhead costing only $40,000 mated to an M26 standard rocket motor, this brings affordable long-range precision to the battlefield.[46] In addition, the rapid, sustained improvements in the range, payload, and speed of drones opens an entirely new field of massed, precision attack. The density of such attacks will be further enhanced by the evolving cruise missiles that can be launched from air, sea, and ground platforms to include transport aircraft, commercial ships, and ground vehicles.

Implications for strategies and policies

By combining new concepts of command and control, persistent surveillance, and massed precision fires, Ukraine has demonstrated game-changing capabilities that are allowing its armed forces to stop the much larger, equipment-rich Russian forces. However widely available this knowledge of Ukraine's success and Russia's failures, enactment of that knowledge into sustainable warfighting capabilities is what will differentiate the future performance of competing armies. But doing so will be hard because it involves substantial change in the entire chain of logic to which current capabilities are tethered. In their concepts, forces, and systems, armies which enjoy competitive advantage in the twenty-first century will overcome these barriers to enact more quickly the implications of what the Russo-Ukraine war is revealing, among them—

Recognize that these game-changing capabilities are giving new and powerful advantages to defenders in ground combat. While this precept does not necessarily mean offense will be impossible, it will certainly be much more costly. Defenders can minimize their signatures in numerous ways, from overhead cover, to simply remaining stationary, to deliberate camouflage. Defenders do not have to reveal themselves until they choose to fire. Then, using local knowledge, defenders can preplan rapid displacement to alternative covered positions after they fire. Further, in ground combat, offensive routes are often defined by terrain that forces the attacker to concentrate. In contrast, long-range weapons enable the defender to concentrate fires without concentrating forces and thus remain dispersed. And, by definition, the attacker must move—and that will generate multiple signatures.

Structure and organize forces to operate in an environment of ubiquitous surveillance. Hundreds to thousands of autonomous, loitering munitions will be

41 Fatma Kahled, "Ukraine Shoots Down Nearly 90 Iranian-Made Drones in Two Days: Zelensky," *Newsweek*, January 2, 2023, https://www.newsweek.com/ukraine-shoots-down-nearly-90-iranian-made-drones-two-days-zelensky-1770742.

42 Mia Jankowicz, "Iranian-made Drones Cost as Little as $20,000 to Make but up to $500,000 to Shoot Down, a Growing Concern in Ukraine, Report Says," *Business Insider*, January 4, 2023, https://www.businessinsider.com/suicide-drones-much-cheaper-launch-than-shoot-down-ukraine-nyt-2023-1.

43 "Russia Ordered 2,400 Shahed-136 Kamikaze UAVs from Iran," mil.in.ua, October 11, 2022, https://mil.in.ua/en/news/russia-ordered-2-400-shahed-136-kamikaze-uavs-from-iran/.

44 Sam Tabahriti, "Ukraine is Raising Funds to Build a Strike Force of 1,000 Exploding Drones to Help Defeat Russia," *Business Insider*, January 22, 2023, https://www.businessinsider.com/ukraine-wants-strike-force-1000-kamikaze-drones-help-defeat-russia-2023-1#.

45 Isabel van Brugen, "Ukraine Plots to Win 'War of Drones' Against Russia," *Newsweek*, February 20, 2023, https://www.newsweek.com/ukraine-plots-win-war-drones-russia-anton-gerashchenko-1782362.

46 Mike Stone, "Exclusive: U.S. Weighs Sending 100-Mile Strike Weapon to Ukraine," Reuters, November 28, 2022, https://www.reuters.com/business/aerospace-defense/100-mile-strike-weapon-weighed-ukraine-arms-makers-wrestle-with-demand-sources-2022-11-28/.

actively hunting ground forces. Thus, the first priority is to configure a force to survive in the emerging environment. The force will have to blend in, seek overhead cover, or move quickly and frequently to avoid being targeted by the expanding variety of drones, missiles, and smart artillery/mortar ammunition. The force must be designed to operate without big bases or the so-called "iron mountains" characteristic of twentieth-century warfare. It must be trained to operate in a disaggregated manner. The days of massed columns of vehicles and operations from large garrisons are passing.[47] Making the transition will require a large-scale, honest effort to develop the concepts, tactics, techniques, procedures, and equipment for such a force.

Such a ground force will need to shift from the current focus on major platforms to a focus on platform-agnostic, semiautonomous weapons. These weapons can provide effects at much greater range and at much less cost than today's key ground systems. An M1A2 Abrams main battle tank costs at least $9 million. Several semiautonomous, loitering munitions already exist but cost in the hundreds of thousands while ranging out from 15 km to 1,000 km. Thus, a nation could purchase dozens of such missiles for the cost of a tank. Ukraine has demonstrated that these weapons both can be man-portable and can be operated from small vehicles.

Accommodate to combat in which large numbers of "semiautonomous" loitering munitions are battle royalty.[48] A significant degree of autonomy will be necessary to truly exploit the exponential warfighting potential in the vast number of loitering munitions on future battlefields. There are two reasons for this. First, it reduces the EW threat to these systems and, second, it obviates the need to recruit and train thousands of drone pilots who would be necessary for major swarm operations.

Large numbers of these systems can be dispatched to the general location of enemy forces and then engage autonomously. Because they are autonomous, they will not be vulnerable to jamming the operator's signal. And, as noted, advanced manufacturing has the potential to produce these systems in the thousands. While most current drones still rely on GPS signals and thus have the potential to be jammed, commercial firms and defense departments are pursuing multiple technologies that will provide GPS-independent navigation.

The exceptional success of semi-autonomous munitions in the Nagorno-Karabakh conflict and the Russo-Ukraine war has resulted in increased interest and investment in these systems. In 2021, the Brookings Institution reported that "China, Israel, Iran, Russia, Taiwan, Turkey, and the United States all have domestic loitering munition production. Other countries with loitering munitions have bought them from major manufacturers, including Azerbaijan, Germany, India, and South Korea."[49]

Thousands of videos from Ukraine have demonstrated that small drones can track the movement of even individual infantrymen. The question ground commanders must answer is how they will operate when the enemy can surge hundreds of loitering munitions that not only observe but strike.

Recognize ground-based missiles and drones as key instruments of air power. In a first step to establish air superiority, Russia engaged 75 percent of Ukraine's fixed air defense sites during the first forty-eight hours of the war. But it was unable to defeat Ukraine's mobile air defense systems.[50] By March 20, 2023, the Ukrainian Ministry of Defense claimed to have destroyed 305 fixed-wing aircraft and 290 helicopters.[51] Russia's failure led some analysts to state that modern air defense systems can create an area of air denial where crewed aircraft cannot operate. And, in fact, Russian and Ukrainian crewed aircraft rarely attempt to penetrate the multilayered air defense of the other side.[52]

Accordingly, to prosecute its air campaign, Russia shifted to drones and missiles. By committing hundreds of

47 The required changes to airpower concepts and equipment are beyond the scope of this paper, but the current structure is becoming less viable each day.

48 This paper uses the term "semiautonomous" to characterize this attribute because fully autonomous weapons simply do not and cannot exist: People will still be required to design, program, establish rules of engagement, and set standard operating procedures for all weapons prior to launch. Thus, these weapons are more correctly identified as semiautonomous. Once launched, however, they indeed will be able to fly to the designated area and identify and attack targets without further human inputs.

49 Kelsey Atherton, "Loitering munitions preview the autonomous future of warfare," *Tech Stream*, August 21, 2021, https://www.brookings.edu/techstream/loitering-munitions-preview-the-autonomous-future-of-warfare/.

50 Zabrodskyi et al, "Preliminary Lessons in Conventional Warfighting."

51 "The Total Combat Losses of the Enemy from 24.02.22 to 20.03.23," Ministry of Defense of Ukraine, March 20, 2023, https://www.minusrus.com/en.

52 Maximillian K. Bremer and Kelly A. Grieco, "Air Denial: The Dangerous Illusion of Decisive Air Superiority," Atlantic Council, August 30, 2022, https://www.atlanticcouncil.org/content-series/airpower-after-ukraine/air-denial-the-dangerous-illusion-of-decisive-air-superiority/.

Ukrainian S-125 battery firing during "United Efforts 2021." Older systems likes these make up a substantial portion of Ukraine's air-defense forces. Credit: Ukraine Air Force/ Mil.gov.ua. https://commons.wikimedia.org/wiki/File:UA_anti-air_training_2021_S-125M1_(1).jpg.

weapons to its air campaign, Russia has caused significant damage to the Ukrainian electrical grid but has failed to disable it. In response, Ukraine integrated a variety of missile and gun systems and claims it is shooting down 80 percent of the attacking drones and missiles.[53]

The ability to deny airspace to crewed aircraft while destroying most penetrating drones and missiles is shifting the balance in the air domain also to the defense. The inability of even the US Air Force to consistently find and destroy mobile missile systems in the past may mean this shift will extend from Ukraine to any conflict between modern militaries. Long-range drones and missiles will further degrade the capabilities of crewed aircraft by attacking those aircraft at their home bases. This development will require militaries to invest heavily in air defense systems to protect their airbases.

Many nations are pursing laser and microwave systems to defeat drone swarms that, if effective, will further empower air defense for two reasons:

> First, they require large power systems to operate. Attackers must bring those power systems with them and thus the power available is limited by the ability to lift it by land, sea, or air. In contrast, the defenders can either tap directly into the national power grid for virtually unlimited power or use as many generators as they need. Second, the defender has the enormous advantage of blending into the cluttered ground environment . . . As directed energy weapons become operational, they will increase the advantage the defense holds over the offense in the air domain.[54]

53 "Western Air-Defence Systems Help Ukraine Shoot Down More Missiles," *Economist*, November 6, 2022, https://www.economist.com/europe/2022/11/06/western-air-defence-systems-help-ukraine-shoot-down-more-missiles.

54 T.X. Hammes, "The Tactical Defense Becomes Dominant Again," *Joint Force Quarterly*, no. 103 (October 14, 2021), https://www.960cyber.afrc.af.mil/News/Article-Display/Article/2810962/the-tactical-defense-becomes-dominant-again/.

In Ukraine, airpower's role is being executed by a mix of crewed aircraft, drones, missiles, long-range rockets, and integrated air defenses. Future conflicts will impose heavy costs on those nations that continue to see crewed aircraft as the primary source of airpower. To be affordable and succeed, offensive air may have to rely very heavily on land-based drones and cruise missiles.

Engage the commercial sector as a key source of technology and innovation. Most of the technologies driving this change were derived from commercial developments and thus will advance more rapidly than most government projects. Today, commercial firms drive the bulk of investment into satellite surveillance, drone development, AI, and advanced manufacturing. The exponential drop in the cost of precision-guidance technologies driven by commercial markets plus the emergence of advanced manufacturing will make the production of tens of thousands of long-range, precision weapons possible.

Conclusion

The convergence of three key developments in the Russo-Ukraine War is rapidly changing the character of ground combat: pervasive surveillance, massed, precise fires, and a command-and-control system that exploits the two. The implications of these changes for operating concepts, forces, and systems are profound. Emerging technology is vital to each capability, but, like the development of the blitzkrieg or carrier aviation, these transformational capabilities can only be realized by combining several technologies effectively and implementing them in coherent, well-trained operational concepts. Effectively implemented in coherent strategies, the integration of these three capabilities holds the potential to transform the future of ground warfare by giving advantage—perhaps even dominance—to tactical defense.

Historically, transitions to new forms of warfare have taken decades unless accelerated by war. The transition from the large, foot-mobile infantry divisions of World War I to the fully mechanized/motorized divisions needed for World War II took two decades. The shift from battleship-dominated navies to carrier-dominated navies took just as long. In both cases, the outbreak of World War II accelerated the development of the concepts to exploit these new systems as well as the willingness to do so.

Unfortunately, today's rate of change does not allow the United States and its allies and partners the luxury of two decades to transition to twenty-first century warfighting. Nor do these nations possess the resources to simultaneously upgrade all of their forces across the board. Yet failure to do so places US and allied forces at risk in any near-peer conflict. Historically, successful transitions require building game-changing capabilities while adapting existing forces to maximize their support to the new concepts.

For now, the United States should focus on accelerating the integration of the three game changers: pervasive surveillance, advanced command and control, and mass, precise fires. Pervasive surveillance requires integrating the exponentially expanding commercial multispectral, radar, and electromagnetic surveillance systems into its combat systems. Developing advanced command and control means understanding how Ukraine developed the Delta system and adapting those techniques to the Pentagon's agonizingly slow development of JADC2. Finally, achieving mass, precise fires will require shifting from the United States' current inventory of expensive, exquisite platforms to cheaper, simpler weapons produced through advanced manufacturing. Only by doing so can the US military achieve the mass required in major conflict.

Effective investment will strengthen the defensive capabilities of the joint force. It will also provide the opportunity to share these more affordable systems with our allies. Given that the United States and its allies and partners are essentially on the defense in both Europe and Asia, the convergence of these capabilities truly hold the potential to change the game of ground warfare in the twenty-first century.

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