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Brief

Fortification for Drone Warfare

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High-intensity drone warfare has shattered assumptions about how defensive positions should be built. In 2025, Ukraine discarded Cold War-era doctrines to embrace a paradigm of scattered, low-observable, and fluid strongholds supported by distant fire control and rapidly deployed counter-Uncrewed Aerial Systems (UAS). This brief offers a blueprint for fortification in the drone age, emphasising end-user-informed design, dispersion, concealment, modularity, and small-unit adaptability.

Russia's war in Ukraine marks the transition to a new era of warfare, characterised by the widespread employment of UAS and, increasingly, lethal autonomous systems. The engineering of defensive lines and fortifications stands at the forefront of this transformation, as the pervasive use of UAS has put new levels of physical and psychological strain on infantry soldiers. Every soldier on this battlefield is a target, exposed to relentless high-precision threats around the clock, requiring defence planning to move far beyond legacy doctrines ill-suited to the new operational realities.

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From Trenches to Shadows

The Armed Forces of Ukraine's (AFU) approach to fortification has undergone significant adaptation during the war. In the early period, both sides adhered to classical Soviet-era doctrines that emphasised the concentration of forces and materiel in large strongholds, heavily fortified against the primary threats of massed artillery fire and major infantry assaults supported by armoured vehicles. The AFU abandoned this approach around the middle of 2023, although segments of vast fortifications have continued to be occupied situationally by small groups of manoeuvring infantry.[1] Some legacy components, such as anti-tank ditches, 'dragon's teeth' obstacles, and extensive minefields, have also remained relevant, even growing in importance to defend against the 'meat assaults' conducted by small, dismounted Russian infantry groups.

From summer 2023, the proliferation of 'kamikaze' first-person view (FPV) drones, bomber drones, and reconnaissance-strike complexes (RSC) pairing UAS with artillery and missile systems achieved a saturation point, affording near-unlimited and ubiquitous tactical precision strike capabilities. The density of reconnaissance and attack drones effectively established a five- to ten-kilometre-deep 'kill zone' along the contact line in which conventional fortifications—wide trenches, large platoon or company-sized dugouts, and concentrated strongpoints—became highly vulnerable and increasingly unusable. For example, during the battle for Avdiivka (autumn 2023 to February 2024), perfectly situated and heavily fortified Ukrainian positions fell after systematic attacks by FPV and bomber drones and drone-guided artillery and glide bomb strikes that targeted strongholds, individual dugouts, command posts, trenches, and logistics routes.[2] Reinforcement and rotation in Avdiivka became hazardous and ultimately unfeasible.[3]

Still, state contractors continued to build fortifications according to outdated standards, especially when end-user tactical units were not involved in planning.[4] Their unsuitability was starkly exposed during the initial stages of Russia's Kharkiv offensive in May 2024.[5] Extensive and costly 'soviet-style' border fortifications proved to be largely untenable, were often constructed in indefensible locations, and became prime targets for Russian reconnaissance and precision fire. Ukrainian units were forced to abandon such positions in favour of more mobile defensive tactics.

Fortifications continue to evolve towards even greater deepening and dispersal, enhanced concealment, and nascent robotisation

At the same time, however, proactive, battle-hardened tactical units began to independently adapt, design, and construct fortifications aligned with the new realities. By late 2024, the top military command had finally recognised the need for a strategic-level reassessment and primary responsibility for fortification construction was transferred to a dedicated state operator, the State Special Transport Service (SSTS).[6] The SSTS applied lessons learned on the battlefield to plan and construct second-line fortifications to meet infantry needs across the entire front.

Combat in 2025 has evolved into a drone-enforced attrition as UAS have grown in numbers and quality, and the pool of skilled operators has expanded. The kill zone has deepened to perhaps 35-40 km and become more lethal.[7] Drones have become a universal, high-precision tool for attriting personnel and equipment, and the concept of a safe rear 10-15 km from the contact line has largely vanished. Offensive actions are mostly confined to local raids with no prospect of deep breakthrough, while defensive operations have transitioned from active position-holding to passive measures to ensure the survival of small, dispersed groups. In these circumstances, fortifications continue to evolve towards even greater deepening and dispersal (including single-person positions), enhanced concealment, and nascent robotisation.

Lessons for Engineering

The AFU's experience has yielded critical insights that impose new requirements on fortification design and construction. First, as UAS now pose the most severe threat to dismounted infantry (strike drones are responsible for up to 80% of personnel casualties, and RSC for a further 15%), personnel and assets must be dispersed as much as possible to complicate enemy detection, targeting, and effects. Large strongpoints designed for 30-100+ personnel should be replaced by distributed networks of positions designed for small tactical units of typically three to eight personnel and by an even more granular system of individual fighting positions and autonomous weapon emplacements.[8] To enhance survivability and tactical flexibility, these primary positions must be supported by numerous alternate and decoy locations arrayed in depth across the front.

Military engineering can also contribute to a multi-layered system of drone defences. Camouflage and concealment from aerial observation require the careful siting of positions within natural cover like tree lines and the construction of access and egress routes to permit safe manoeuvre. Physical protection should include robust overhead cover for all elements above ground, blast entrances, and the internal segmentation of trenches to mitigate shrapnel and blast effects. Such fortifications must also incorporate chemical, biological, radiological, and nuclear protection, including proper seals and air filtration, multiple concealed entry and exit points to covered or subterranean passages, and as great a shelter depth as local hydrogeological conditions permit. Finally, this defensive network must be supported by pre-planned, camouflaged logistical shelters along approach routes to facilitate safer rotation and resupply operations.

Second, as dispersal will result in reduced force densities, engineering solutions that allow long fronts to be held with minimal manpower must be found. Solutions that facilitate manoeuvre and proactive defence while prioritising personnel survivability will involve increasing the depth of the entire defensive area to 25 to 40 kilometres, with a spacing of 400 to 600 metres between defensive lines. This will create integrated, layered fields of fire control that can be supported by explosive and non-explosive (e.g., wire entanglements) obstacles placed on likely enemy avenues of approach to underpin tactical and operational manoeuvre, allow for the establishment of 'kill pockets', and optimise the employment of limited forces.[9] The over-reliance on extensive concrete works, which are very visible and difficult to recapture if compromised, must be replaced by the construction of primary defensive lines interspersed with numerous alternative positions connected by protected routes for inter-position manoeuvre. Critically, this connectivity should primarily link main positions with their designated alternates rather than with other main positions, reducing the risk of an enemy exploiting a single breach to roll up an entire strongpoint.

Deception is fundamental: combat commanders recommend that at least 50% of all emplacements should be decoys. Fortifications must also include infrastructure to support unmanned ground systems, such as prepared firing positions for remotely operated weapons sited to cover unit boundaries and gaps. Finally, as troop rotation can be risky under pervasive drone surveillance, defensive positions must include integrated lodging facilities to support prolonged unit autonomy on the front line.

Third, tactical-level commanders, military engineers, and small unit leaders (e.g., squad leaders who are to occupy the defences) must be involved in the design and construction of any defensive works. As these must directly support the commander's concept of operations and the designated order of battle, each engineering effort should be preceded by detailed reconnaissance, site-specific design, and full integration with manoeuvre, fire, and logistics plans, including the digital mapping of all elements.

The requirement to ensure that defensive positions are tailored to the specific defensive concept and the established tactics, techniques, and procedures of the occupying unit points to a new standard where draft designs are developed, or at least significantly informed, by the intended users, approved at the appropriate operational level, and only then executed by engineering assets or contractors. This might be facilitated by the development and fielding of a wide range of modular, prefabricated components that commanders can adapt to specific tactical requirements. Technical specifications for the most forward-deployed modules must allow for manual emplacement: individual components should not exceed a weight manageable by a small team. Furthermore, a minimal kit for individual position construction should be developed for situations when logistics are constrained. Components should weigh no more than 10-15 kg to be portable by infantry soldiers.

Conclusion

Until such time as front-line personnel are replaced by machines, fortification engineering will remain a priority. The preservation of the most valuable asset in modern warfare—the soldier—requires an innovative leap in military engineering commensurate with the advancements in lethal drone technology. As UAS become more resilient to electronic warfare and their autonomy, precision, and manoeuvrability increase, it is military engineering that will build the core of personnel protection systems.

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Based on lessons learned during three-and-a-half years of fighting, the AFU have begun this adaptation process. Not all lessons, however, will be translatable to other situations, especially those where operational depth is limited, land corridors more compact, and adversary military

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concentrations closer, i.e., situations in which defence-in-depth may not be tenable.

Finally, despite the importance of military engineering to battlefield success in drone warfare, it is important to recognise that obstacles and fortifications must also be integrated with a comprehensive reconnaissance and engagement system. Without effective surveillance and timely response capabilities, fortifications risk becoming traps for the personnel they are intended to protect.

Endnotes

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Sahaidachnyi Security Center is a Ukraine-based security and defence think-tank. Due to the sensitive nature of this brief, it has requested not to disclose the individual experts from its team who have authored it.

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