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Winning Without Technological Advantage

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Methodology

Research for this paper was conducted from November 2025 to February 2026 as a contribution to a Ministry of Defence evaluation of how UK forces may mitigate technological disadvantage on the battlefield. To conduct this research, the authors carried out a review of joint and service doctrine across NATO, and a survey of existing technologies represented by programmes of record in friendly and adversary states. The conceptual underpinnings of the research are grounded in historical research, examining historical manifestations of technological advantage and mitigation strategies. The research drew on a wider set of historical case studies than can be covered in the paper, bounded by a focus on modern warfare since 1939. After selecting historical case studies where evident technological differences between actors were identified, the authors surveyed the secondary literature of these conflicts. For those case studies included in the ensuing discussion, the authors also sampled primary historical records associated with the conflict to address specific queries. This included examination of historical imagery and mapping to understand where terrain and other features may have had a disproportionate bearing on the explanation of outcomes. In several instances, where secondary literature clearly demonstrated that an author had considered the impact of technology on events, but had not directly addressed this theme, the authors conducted interviews to ensure their thinking was properly reflected. AI was not used in the process of researching or drafting this paper.

There are limitations to this research. As a short paper, it cannot set out an exhaustive historical survey. The examples discussed are a minority of those examined. Even then, it is still a limited sample. Readers should not take the conclusions as definitive. Rather, they are a framework for thinking about technological advantage and mitigating its absence. This can inform the development of subsequent concepts.

Executive Summary

For the purposes of this paper, 'technological advantage' may be defined as a force fielding technologies that are either more efficient than those available to the adversary or give the force tactical options that the other side lacks. Conceptually, technological advantage is not simply the fielding of more sophisticated equipment, but the advantage that can be derived from that sophistication.

Today, the UK – owing to stalled modernisation of its own armed forces compared with the accelerating modernisation of its adversaries – risks finding itself fighting under conditions of technological disadvantage. Although this should ideally be avoided, officers should consider how best to prevail on the battlefield from a position of technological inferiority.

To succeed from a position of technological disadvantage, UK forces must avoid allowing the technological gap to reach a point where they are overmatched, especially in the sphere of ISR and countering enemy ISR. Other than the commitment of greater mass, imposing the fog of war on an adversary is a necessary precondition for most strategies to counter adversary technological advantage. Simply applying mass and accepting higher casualties is not a politically acceptable planning assumption for the UK, although it is necessary to consider the generation of mass by fielding cheaper but sufficiently capable systems.

This paper illustrates several approaches to overcoming an adversary's technological advantage that have historically proven effective. One of the most consistent methods is to identify the operational logic of the system offering advantage to an adversary and make targeted investments to counter it. In this way, narrow investment can disrupt an adversary's capacity to derive advantage from a technology, even if its capability cannot be competitively replicated or surpassed.

Another approach that has proven historically reliable is to shape engagements such that a given area of enemy advantage cannot be brought to bear. Shaping the terrain, reach and conditions of an engagement can determine the utility of tools wielded by an adversary. This tactic, however, often requires a plan to exploit the vulnerabilities exposed and therefore demands that a force be offensively minded and to retain the initiative. Effectively using initiative is contingent on having competitive intelligence, reinforcing the foundational nature of ISR in technological competitiveness.

Based on these factors, this paper draws clear conclusions for the UK's capability priorities. These are that:

- The UK should continue to invest so that it remains competitive in ISR and develops a more deliberate approach to counter-reconnaissance.
- The UK should structure engagements to reduce the impact of adversary technological advantage by defending forwards, through its allies, and by limiting adversary escalation options by maintaining the Continuous At Sea Deterrent.
- The UK should prioritise the ability to strike at the logic of how an adversary can employ its technological advantages. At sea, this means prioritising anti-submarine warfare.
- In the air domain, the UK should be offensively orientated and pursue the initiative by prioritising the ability to suppress and destroy air defences, thereby enabling the wider availability of air-delivered firepower from the UK and its allies.
- In the land domain, the priority should be firepower as being disproportionately valuable in augmenting allies and notably enabling the targeting of the centre of gravity of Russian forces: the divisional fires group.
- The UK should explore how it can ensure mass of munitions, even if these are technologically inferior to adversary systems, as mass can often overcome technological sophistication. To do this, the UK needs the manufacturing base and assured supply chains to produce the necessary quantities of materiel.

Prioritising specific capabilities and mission sets can help to set up the UK for fighting under conditions of technological disadvantage. However, being able to use the principles outlined in this paper for the purposes of operational design and tactical execution requires that troops have an appropriate mindset. This can only be inculcated through costly experience or appropriate education and training.

Introduction

This paper considers how British forces can plan and think about operationally overcoming an adversary that holds technological advantage on the battlefield. Beyond conceptually considering how a force might fight under such conditions, it looks at the factors that mitigate technological disadvantage.

The paper seeks to guide the UK Ministry of Defence (MoD) in triaging measures that can compensate for technological disadvantage with targeted investment and tactical development. For the purposes of this paper, 'technological advantage' is defined as a force fielding technologies that are either more efficient than those available to the adversary or give the force tactical options that the other side lacks. Conceptually, technological advantage is not simply the fielding of more sophisticated equipment, but the advantage that can be derived from that sophistication when it is fielded at a sufficient scale and with sufficient competence to make the technology a factor on the battlefield.

The US' Second Offset Strategy,[1] followed by the collapse of the Soviet Union, left NATO members with a presumed technological battlefield advantage that has since dominated their approach to combat. The operational question confronting allies – how to fight outnumbered and win – is, in some respects, consistent in both the planning for a confrontation with the Warsaw Pact in the 1980s and China's People's Liberation Army in 2030. However, the proposed solutions have arguably shifted from seeking tactical advantages, through AirLand Battle, to seeking technological advantage. Indeed, technological advantage is often conceptualised as an intrinsic part of the 'American Way of War', especially by the proponents of a Third Offset Strategy.[2] The British way of war has historically emphasised tactical compensation for resource scarcity, although not necessarily technological backwardness.[3] However, this mindset

1. Robert R Tomes, *US Defence Strategy from Vietnam to Operation Iraqi Freedom: Military Innovation and the New American War of War, 1973–2003* (Abingdon: Routledge, 2006).
2. Andrew Krepinevich, *Origins of Victory: How Disruptive Military Innovation Determines the Fates of Great Powers* (New Haven, CT: Yale University Press, 2023).
3. Basil Liddell Hart, *The British Way in Warfare* (London: Faber & Faber, 1932).

arguably withered during the unipolar era following the Cold War, as ubiquitous access to US capability became a defence planning assumption.[4]

There are three key reasons why it is no longer realistic to presume that the UK will have technological advantage in future conflict. First, the 2026 US National Defense Strategy diverges in focus from UK defence planning assumptions. This might see significant US military disengagement from Europe.[5] Second, the scale of China's military investment and engineering capacity is producing classes of weapon system for which there is no direct analogue, even in the US.[6] In the land, sea and air domains, a proliferation of sophisticated Chinese equipment might pose a serious challenge for European capabilities.[7] Even Russia – lacking China's sophistication and scale of capabilities – has been investing extensively in the modernisation of its weaponry, often based on data from engagements against high-end UK capabilities in Ukraine, and fields a range of capabilities for which there is neither a European analogue, nor a clear counter.[8] Third, the UK has disinvested defence since 1991 to a point where its fleets have shrunk and the nation's capacity to replace them has diminished. In a war, it is far from guaranteed that frontline equipment would improve, rather than degrade, over time.[9]

A secondary context to this paper is the growing divergence between UK threat assessment and policy. While government officials publicly emphasise that the UK is increasingly facing serious threats that could draw the country into conflict, capability – whether in training hours, stockpiles or the pace of modernisation – is in decline. Politicians, moreover, continue to demand a level of output from

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4. Reaffirmed in successive defence reviews. See HM Government, *Global Britain in a Competitive Age: The Integrated Review of Security, Defence, Development and Foreign Policy*, CP 403 (London: The Stationery Office, 2021).
5. US Department of Defense, '2026 National Defense Strategy: Restoring Peace Through Strength for a New Golden Age of America', January 2026.
6. These include, but are not limited to, capabilities to manipulate or disable satellites without destructive effects in orbit. China's on-orbit servicing, assembly and maintenance (OSAM) SJ-21 satellite has raised concerns from the US Space Force due to its ability to physically manipulate satellites out of orbit. Its OSAM satellite is described by Chinese space analysts as a dual-use capability, which could strike space-based C4ISR. NASA has cancelled investment in this capability. See Kristin Burke, 'China's SJ-21 Framed as Demonstrating Growing On-Orbit Servicing, Assembly, and Manufacturing (OSAM) Capabilities', China Aerospace Studies Institute, December 2021, <https://www.airuniversity.af.edu/Portals/10/CASI/documents/Research/Space/2021-12-09%20SJ-21%20and%20China's%20OSAM%20Capabilities.pdf>, accessed 29 January 2023; Jimi Russell, 'Update on Status of NASA's OSAM-1 Project', NASA, 1 March 2024, <https://www.nasa.gov/missions/update-on-status-of-nasas-osam-1-project/>, accessed 29 January 2026.
7. *Military Watch*, 'Serbia Deploys Chinese HQ-22 Surface-to-Air Missile Systems for Anti-Drone Drills in Eastern Europe', 6 February 2026, <https://militarywatchmagazine.com/article/serbia-deploys-chinese-hq22-drills>, accessed 24 January 2026.
8. Jack Watling and Oleksandr V Danylyuk, 'Winning the Industrial War: Comparing Russia, Europe and Ukraine, 2022–24', *RUSI Occasional Papers* (April 2025), <https://www.rusi.org/explore-our-research/publications/occasional-papers/winning-industrial-war-comparing-russia-europe-and-ukraine-2022-24>, accessed 24 January 2026.
9. Edward Stringer, 'The Say-Do Gaps in Defence. The Danger of Carrying a Small Stick While Talking Loudly…', Policy Exchange Research Note, January 2026, <https://policyexchange.org.uk/wp-content/uploads/The-Say-Do-Gaps-In-Defence.pdf>, accessed 24 January 2026.

defence that the force, as currently sized and resourced, cannot sustain. They have essentially been burning the resilience built up by previous decades of investment to live beyond their means. This is not a problem isolated to the current government. However, the UK is approaching a point where it will become disproportionately difficult to recover capability in crisis. This paper, while considering how the UK might approach fighting under conditions of technological disadvantage, therefore, also outlines the painful decisions that must be made by policymakers when they find themselves in that position.

The paper has three chapters. The first discusses how technological advantage manifests on the battlefield. While it would be tempting to methodologically isolate technological advantage as a variable discrete from – for instance – tactics and terrain, the authors have found that it must be discussed in the context of, rather than separated from, other aspects of fighting power. The chapter explores how something conceptually simple – that a more capable military tool offers advantage – actually manifests in complex interactions. The second chapter builds on this by examining how militaries have historically endeavoured to mitigate or even overcome a technological disadvantage. The third chapter discusses how the UK can plan on applying these principles in force design and planning.

Conceptualising Technological Advantage

Technological advantage is, historically, simple to conceptualise in abstract terms or extreme cases, but difficult to isolate as a variable. However, to assess the real-world application of mitigations for being at a technological disadvantage, the analysis of what has – and has not – been successful must also be grounded in practical application. This chapter therefore sets out the challenges in measuring technological advantage before identifying some general principles as to how it has manifested historically.

The Challenge in Identifying Technological Advantage

Conceptually it is not difficult to grasp the idea that a force armed with Martini–Henry repeating rifles has a paradigmatic military advantage over a force armed with spears.[10] However, it is well known that at the Battle of Isandlwana in 1879, 15,000 Zulu troops armed with spears defeated a force of over 1,800 British troops armed with repeating rifles and artillery. There is a problem with extrapolating from individual battles with extreme technological disparity to arrive at stratagems for mitigating an adversary's advantages. For individual cases, the loss is often a result of tactical errors by the commander and was not generalisable to the wider campaign. After all, the Zulu Kingdom won the battle but lost the campaign. Moreover, as military operations have become more complex, involving the interaction of diverse technologically asymmetric systems, it is a challenge to isolate technological advantage as a distinct causal variable from other elements of combat power, or even to determine on whose side technological advantage lay.

10. Paradigmatic changes mean that a technology fundamentally changes the way forces fight because the previous approach to warfare is no longer competitive.

The British-led Operation *Goodwood* in 1944 illustrates the challenge of isolating the effects of technological advantage. Allied forces unsuccessfully endeavoured to break out from the Normandy bridgehead through a numerically inferior German force. Max Hastings argues that weapon-for-weapon, German ground forces were better equipped than their Allied counterparts.[11] However, this is heavily disputed. Stephen Biddle's case study of the operation concludes that the defender – heavily outnumbered German armoured and infantry forces – 'lacked any dyadic technical edge' to counter the Allies' overwhelming advantage in artillery, armour and airpower.[12] The Germans had some platforms that overmatched Allied armour.[13] However, Tiger and Panther tanks were a minority of the German armoured force, with the majority comprising Panzer IVs – comparable to British Shermans and Cromwells – and assault guns. Similarly, the German inventory of 88-mm guns was small compared with less effective 75-mm PAK guns, although the latter accounted for a significant proportion of Allied armoured losses.[14] The Germans did field more mortars[15] and some unique capabilities, such as the Nebelwerfers, in considerable numbers,[16] but this must be placed in the context of a much higher density of Allied supporting fires.

Biddle concedes that the Germans had an advantage in machine guns; this is heavily emphasised in Hastings' argument. However, Richard Fisher has disputed this. Fisher compared the Bren gun and the MG42. He found that the MG42's rate of fire, at 25 rounds per second, was practically unsustainable at cyclic rate due to barrel change frequency and thus, only marginally better than the more accurate Bren gun.[17] This is an instance where a technical analysis arrives at a conclusion that is diametrically opposed to the overwhelming testimony of combatants – both Allied tankers and infantry.[18] Many advantages were also context specific. Army Operational Research Group data suggests that within the bocage where fields had, on average, 300-metre line of sight, and on larger fields on the Caen plain where line of sight could reach over 2,500 metres, the Allies needed more tanks than German defenders to win in

11. Max Hastings, *Overlord: D-Day and the Battle for Normandy* (London: Pan Macmillan, 2024), pp. 236–37.
12. Stephen Biddle, *Military Power: Explaining Victory and Defeat in Modern Battle* (Princeton, NJ: Princeton University Press, 2004), p. 112.
13. Overmatch encompasses a situation in which the capability gap between two platforms should make the outcome of a direct engagement between them certain, consistently favouring one party.
14. Terry Copp, 'Mayhem In Normandy: Army, Part 102', *Legion Magazine*, 23 October 2012, <https://legionmagazine.com/mayhem-in-normandy-army-part-102/>, accessed 24 January 2026.
15. Ethan Rawls Williams, '50 Div in Normandy: A Critical Analysis of the British 50th (Northumbrian) Division on D-Day and in the Battle of Normandy', Master's thesis, US Army Command and General Staff College, 2007, <https://apps.dtic.mil/sti/tr/pdf/ADA475698.pdf>, accessed 24 January 2026.
16. Jonny Briggs, '"Tanks in Unexpected Places": The Fighting Effectiveness of 4th (Independent) Armoured Brigade, 1943-45', PhD thesis, University of Buckingham, April 2023, <https://bear.buckingham.ac.uk/655/1/1103363%20Briggs%20J%20-%20Tanks%20in%20Unexpected%20Places%20240423.pdf>, accessed 24 January 2026.
17. Richard Fisher, 'Comparing Historic Military Capabilities: Apples with Apples', *RUSI Journal* (Vol. 169, No. 1–2, 2024), pp. 76–90.
18. *Ibid.*

armoured engagements.[19] Firing first was found to be critical. This favoured German defenders, equipped with low-profile anti-tank guns, in close terrain, while at longer ranges, Allied armour losses were double that of close terrain, partly because of the higher silhouette of their vehicles.[20] Purely comparing armoured platforms misses the wider Allied advantages in support systems such as artillery and, most importantly, in the air. The latter allowed the Allies to drop the equivalent of 8 kilotons of explosives onto German positions during Operation *Goodwood*.[21] And yet, Operation *Goodwood* failed to achieve aims outlined by Field Marshal Bernard Montgomery to General Miles Dempsey in a 15 July directive outlining a 'domination' of terrain combined with enemy force 'destruction'.[22]

From the above, it is possible to identify two different aspects of technological advantage. First, a force with technological advantage can do things the other side cannot: Allied airpower, for example, allowed commanders to bring capabilities to bear that the Germans could not. To give a more recent example, the US could draw on satellite surveillance of Iraq in 1991, while Iraqi forces lacked over-the-horizon reconnaissance. Second, technological advantage allows a force to be more efficient in a task than its opponent. It is a tactical reality – for example – irrespective of what a technical analysis of the weapons might suggest, that the MG42 proved more effective at delivering suppression than the Bren gun.[23] Technology, in other words, either does the same things as an opposing system, but better, or it allows a force to do different things. So how can the scale of technological advantage conferred be measured?

Technological Advantage is Non-Linear

The size of the gap between otherwise comparable technologies affects the scale of the advantage conferred. However, the divergence in advantage is non-linear. For example, a modern F-16V with appropriate missiles is technologically superior to the Russian Su-35S. In a direct engagement, all things being equal, the F-16V should win. However, a force using Su-35S with good pilots, training and a sound concept of operation, could plausibly hold a force employing F-16Vs at risk and indeed deny it the opportunity to successfully achieve its mission. This would not be the case if the Su-35Ss were to face a force of F-35s or F-22s. In that case, the Su-35S would struggle to detect these aircraft

19. Marc Milner, 'Reflections on Caen, Bocage and the Gap: A Naval Historian's Critique of the Normandy Campaign', *Canadian Military History* (Vol. 7, No. 2, 1998), pp. 7–17.
20. US Army Operational Research Group, 'A Survey of Tank Warfare in Europe from D-Day to 12 August 1944', Memorandum No. C.6, 27 May 1952, <https://lmharchive.ca/wp-content/uploads/2014/08/Survey-of-Tank-Warfare-in-Europe.pdf>, accessed 4 February 2026.
21. Thomas G Bradbeer (ed.), *Lethal and Non-Lethal Fires: Historical Case Studies of Converging Cross-Domain Fires in Large-Scale Combat Operation* (Fort Leavenworth, KS: Army University Press, 2018).
22. Christopher Dunphie, *The Pendulum of Battle: Operation Goodwood, July 1944* (Barnsley: Pen & Sword, 2004), p. 31.
23. Stephen Bull, *World War II Infantry Tactics: Squad and Platoon* (Oxford: Osprey, 2004).

and, if they managed to acquire the track, would thereafter find it extremely difficult to lock with radar. It would be highly likely that a less competent F-22 pilot would defeat a more competent Su-35S pilot. The technological gap is simply too great. At this level of advantage, the technological advantage may be termed 'overmatch'.

The difference between overmatch and advantage may be seen in the first weeks of Russia's full-scale invasion of Ukraine in 2022. Russian aircraft overmatched Ukraine's MiG-29s and Su-27s, blinding their radar, outranging them, being able to track them while manoeuvring, and maintaining communications while Ukrainian communications were jammed. If the fight had simply been a contest between the air forces, Ukraine would have lost decisively, despite the professionalism and courage of Ukraine's pilots. But Russia did not achieve this level of technological overmatch in the interaction between its aircraft and Ukrainian air defences. Here, Russia's initial advantage of surprise, some careful planning and some technological vulnerabilities in Ukraine's air defence allowed the Russians to suppress Ukrainian surface-to-air missile (SAM) sites sufficiently to enable several air assault operations deep into Ukrainian territory.[24] As the air defence network's command and control (C2) recovered, however, it was clear that, while inferior to their Russian counterparts, Ukrainian SAMs were still able to track and engage Russian aircraft such that the Ukrainians successfully closed their airspace. While better training in the Russian Aerospace Forces (VKS) might have allowed the Russians to begin breaking into the airspace again, the competent tactics, techniques and procedures of Ukrainian air defence units continued to pose a high threat to Russia's air operations. With time, Ukraine was still operating from a place of technological disadvantage but was no longer overmatched.

The Vietnam War also demonstrates how a technological edge must often exceed certain thresholds before it can confer a meaningful advantage. During the 77-day siege of Khe Sanh air base, US aircraft dropped 98,721 tons of bombs on North Vietnamese Army (NVA) positions, in addition to ground forces firing over 158,000 artillery rounds. The NVA had no air capability. In artillery, the volume of fire was lopsided, with estimates of NVA fire ranging from only 15,000 to 30,000 explosive rounds expended,[25] with a recorded peak on 23 February 1968 of 1,307 rounds landing on the base.[26]

24. Justin Bronk with Jack Watling and Nick Reynolds, 'The Russian Air War and Ukrainian Requirements for Air Defence', RUSI, 7 November 2022, <https://www.rusi.org/explore-our-research/publications/special-resources/russian-air-war-and-ukrainian-requirements-air-defence>, accessed 29 January 2026.
25. Brian Nielson, 'The Battle of Khe Sanh: A Fourth Touchstone Battle for the Marine Corps', *Leatherneck Magazine*, 15 November 2025, <https://www.mca-marines.org/leatherneck/writing-winner-the-battle-of-khe-sanh/>, accessed 24 January 2026.
26. John T Correll, 'All Eyes on Khe Sanh', *Air Force Magazine* (March 2016), pp. 60–65, <https://www.airandspaceforces.com/PDF/MagazineArchive/Magazine%20Documents/2016/March%202016/0316eyes.pdf>, accessed 1 April 2026.

The US therefore had a massive advantage in the volume of available materiel, but also had clear technological advantages. Although the NVA had some minor technological advantages, such as its 130-mm guns outranging US 155-mm howitzers,[27] the US had air and ISR capabilities for which the NVA had no comparable technologies. The US used these capabilities to endeavour to overcome the dense vegetation around Khe Sanh that obstructed artillery spotting.[28] US forces were able to use air-deployed unattended ground sensors to monitor seismic and acoustic signatures for the detection of the enemy.[29] The feeds from these sensors were relayed by orbiting aircraft.[30] At Tan Son Nhut air base, US Air Force intelligence teams were gathered to examine reconnaissance photography, including geospatial imagery, requiring 200 staff.[31] Despite the asymmetry in the volume of fires, however, the technological advantage from US ISR did not translate into substantially more accurate fires. The US succeeded in holding off the NVA. However, careful concealment, disbursal, infiltration and taking advantage of weather conditions, meant that the NVA could endure and wear down US defenders, albeit suffering considerably more losses.[32] Closely examining casualty data and operations in the Khe Sanh area between 1967 and mid-1968, Peter Brush argues that the 'siege' resulted in stalemate and ultimate US withdrawal.[33] Fighting resumed in 1970, involving the NVA 304th Division, reconstituted following the 1968 battle.[34] The NVA was therefore neither deterred nor forced from the battlefield. In some respects, the NVA was more efficient in the effect caused with its fewer shells fired. US ISR therefore, while technologically sophisticated, was not sufficiently capable to enable US materiel advantages to be decisive.

In addition, technological advantage has a highly context-dependent relationship with morale. In several instances, being at a disadvantage, even one which was largely perceived rather than material, had a negative psychological impact. Scholars have long sought to understand the relationship between technological and tactical advantage. Typically, they have found that combat power is a function of training, equipment, detailed and timely intelligence and firepower, but is also crucially underpinned by the 'will to fight'. These elements cannot be easily disentangled.

27. Shawn P Callahan, 'Close Air Support and the Battle for Khe Sanh', US Marine Corps History Division Occasional Paper, 2009, <https://www.marines.mil/portals/1/publications/close%20air%20support%20and%20the%20battle%20for%20khe%20sanh%20%20pcn%2010600090000_2.pdf>, accessed 24 January 2026.
28. R D Camp Jr, 'Memories of Khe Sanh', *Naval History* (Vol. 18, No. 1, 2004).
29. *Ibid.*
30. Walter J Boyne, 'Airpower at Khe Sanh', *Air & Space Forces Magazine*, 1 August 1998, <https://www.airandspaceforces.com/article/0898vietnam/>, accessed 1 April 2026.
31. *Ibid.*
32. Correll, 'All Eyes on Khe Sanh'.
33. Peter Brush, 'Battle of Khe Sanh: Greatest U.S. Victory in Vietnam – or Worst Defeat?', Historynet, 26 June 2007, <https://www.historynet.com/recounting-the-casualties-at-the-deadly-battle-of-khe-sanh/>, accessed 5 February 2026.
34. *New York Times*, '384 of the Enemy Reported Killed in Khe Sanh Fight', 13 July 1970.

The latter has been described as the 'single most important', element of combat power,[35] and it is partly shaped by the perceived competitiveness of capabilities.[36] The psychological impact of being ill-equipped can hold even in training exercises with better equipment, where forces have in some instances reported feeling helpless, even when not in mortal danger.[37] A perception of being at a technological disadvantage can be paralysing. During the aforementioned Operation *Goodwood*, the belief of Allied forces that their equipment was uncompetitive caused sluggishness in several units.[38] Technological disadvantage is not always correlated with the reality and can, in some cases, be a psychological crutch to justify the results of poor tactical performance. This was arguably the case with the British Army in the first phases of the North Africa campaign.[39]

In summary, therefore, assessing technological advantage and its effects requires an appreciation of:

- whether a force is simply more efficient or can do different things than its opponent because of the technology it fields;
- whether the scale of advantage conferred is tactically surmountable or if there is overmatch; and
- how large the gap is perceived to be by one's own troops.

Systems Advantage Versus Platform Advantage

The comparison of the technologies employed by opposing militaries is often conducted at the platform level. The relative thickness of armour, speed and firepower of armoured fighting vehicles, for example, are directly comparable on a like-for-like basis. Comparing groupings of technologies – or systems – however, is not only more complex but also more important.

For instance, a platform-centric view would conclude that the German army had complete overmatch against Poland in 1939 and that France had technological advantage over Nazi Germany in 1940. When assessing platforms, German forces indeed had almost complete technological superiority against Poland in all domains.[40]

35. Ben Connable et al., 'Will to Fight: Returning to the Human Fundamentals of War', RAND Research Summary, 13 September 2019, <https://www.rand.org/pubs/research_briefs/RB10040.html>, accessed 24 January 2026.
36. Briggs, '"Tanks in Unexpected Places"'.
37. Ben Barry, *The Rise and Fall of the British Army: 1975–2025* (Oxford: Osprey, 2025), p 139.
38. Hastings, *Overlord*, pp. 282–313.
39. Robert Forczyk, *Desert Armour: Tank Warfare in North Africa: Beda Fomm to Operation Crusader, 1940–41* (Oxford: Osprey, 2023).
40. Roger Moorhouse, *First to Fight: The Polish War 1939* (London: Penguin, 2019), p. 19.

As it turned out, German forces underperformed in the campaign on a systems level, as they lacked deep experience of combined arms operations at that point. While they had planned how to fight with their new platforms as a system, they had yet to deploy this at scale. As a result, they suffered several setbacks. At Ochota and Wola, on the outskirts of Warsaw, the 4th Panzer Division was repulsed in a series of well-positioned ambushes, then reassigned to fighting at Bzura.[41] There, Polish infantry had moved to launch a counterattack under cover of darkness, and the 4th Panzer Division suffered more attrition, losing a third of its Panzer IV tanks and taking 1,600 casualties in 10 days of fighting.[42] However, when German forces synchronised aerial and artillery attacks on Polish defenders at Bzura, the result was the collapse of the Poznan and Pomeranian armies with 50,000 casualties and 170,000 captured.[43] This illustrates that technological overmatch may lead to tactical – but rarely operational – setbacks. It underlines the importance of having a systems-centric view.

It is likely that the same platform-for-platform comparison would conclude that France had, on balance, technological advantage in 1940. The French army had a higher level of mechanisation than the Germans, while its equipment was, in many instances, competitive with or superior to German equivalents. However, German mobile radio communications rendered its disparate capabilities a fighting system that could outpace France's ability to coordinate a response.[44] The complementarity of German fighting systems and the ability to coordinate them allowed the Wehrmacht to bring about an operational collapse of French resistance. This was evident during Heinz Guderian's crossing of the Meuse, a complex wet gap crossing initiated by understrength elements of the 1st Panzer Division, where considerable risk was mitigated by close air–ground coordination between Fliegerkorps II and XIX Panzer Corps, suppressing French defenders.[45] This was not a question of German forces being better trained, but rather of fielding technologies that made multiple platforms mutually reinforcing force multipliers. They could therefore do things that French forces struggled to match. When it tried to replicate German methods, such as during Charles de Gaulle's operations at Montcornet, the French Army lacked the technological enablers to maintain the necessary momentum or mutual support.[46]

Examining technological advantage through the lens of systems allows evaluation of forces that fight using very different concepts of operation. Libya's wars with Chad in the 1980s initially saw the Libyans wield significant technological advantages.

41. *Ibid.*, p. 145.
42. Richard Hargreaves, *Blitzkrieg Unleashed: The German Invasion of Poland 1939* (Mechanicsburg, PA: Stackpole, 2008.), p. 265.
43. *Ibid.*, p. 161.
44. Julian Jackson, *The Fall of France: The Nazi Invasion of 1940* (New York, NY: Oxford University Press, 2003).
45. Martin van Creveld, Steven L Canby and Kenneth S Brower, *Air Power and Manoeuvre Warfare* (Maxwell Air Force Base, AL: Air University Press, 1994), p. 50.
46. Julian Jackson, *A Certain Idea of France: The Life of Charles de Gaulle* (London: Penguin, 2019), Chapter 5.

Libya had both superior aerial reconnaissance and strike aircraft, including Su-22s,[47] Tu-22 bombers and Mi-24D attack helicopters.[48] It also had heavy artillery and armour. Initially, Chad fielded none of these capabilities, or clear counters to them. In time, however, Chad acquired LAW[49] and MILAN[50] anti-tank missiles, and man-portable air defence systems (MANPADS) that forced Libyan bombers to fly at higher altitude,[51] and space-based ISR support from the US. Each side therefore had capabilities the other lacked. But in the context of a protracted and dispersed conflict over a large area of desert, the specific grouping of technologies that conferred operational advantage could begin to be evaluated. Tactically, Libya retained technological advantages, evidenced by a string of battlefield victories between 1981 and 1983.[52] The density of Libyan tactical reconnaissance should have been more than a match for Chad's low-fidelity and high-latency satellite imagery.[53] But given the long distances involved and the operational mobility conferred by Chad's system of fighting, its satellite imagery was perfectly adequate to inform decision-making within the latency of Libya's capacity to redeploy. Thus, over time, Chad began to set up engagements that were ever-less favourable for Libyan forces. The result was a series of significant defeats for Libyan forces, at Wadi Doum, Fada and Faya-Largeau in 1987,[54] despite the CIA assessing that the Libyans had 'firepower sufficient to prevent the Chadians from seizing Libyan garrisons'.[55]

In short, while the technological balance between the platforms on each side arguably favoured the Libyans at the tactical level, the Chadians built a system of technologies that conferred operational-level advantages such that their tactical engagements denied Libya the ability to leverage its advantages – underlining the differences between a platform advantage versus a systems advantage.

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47. Kostas Chalastras, '"We Know That it is Better to Have a Good TOYOTA than a T-55". Key Battles and Outcomes in the Chad-Libya Conflict', Historia Scripta, 23 April 2024, <https://www.historiascripta.org/post-ww2/we-know-that-it-is-better-to-have-a-good-toyota-than-a-t-55-key-battles-and-outcomes-in-the-chad-libya-conflict/>, accessed 24 January 2026.
48. John Greenwald, 'Disputes Raiders of the Armed Toyotas', *Time Magazine*, 21 September 1987, <https://time.com/archive/6710401/disputes-raiders-of-the-armed-toyotas/>, accessed 24 January 2026. See also, Eastern Order of Battle, 'Libyan Air Force Order of Battle Between 1983 and 1987', <https://easternorbat.com/african_af/Libyan-AF/libyan_air_force_1987/libyan_air_force_1987.html>, accessed 5 February 2026.
49. James Brooke, 'Modern Arms a Key Factor in Chadian Gains', *New York Times*, 2 April 1987.
50. *LA Times*, 'Chad Reports It Has Checked Drive by Libyan-Backed Rebels', 16 February 1986.
51. Brooke, 'Modern Arms a Key Factor in Chadian Gains'.
52. Kenneth M Pollack, *Armies of Sand: The Past, Present, and Future of Arab Military Effectiveness* (Oxford: Oxford University Press, 2019), p. 282.
53. US National Photographic Interpretation Center reports contain detailed information on the composition and location of Libyan units and defences but cannot explain where Libyan units were redeployed from. See National Photographic Interpretation Center, 'Libyan Forces Return to Faya Largeau', CIA-RDP92T01321R000200310004-6, <https://www.cia.gov/readingroom/docs/CIA-RDP92T01321R000200310004-6.pdf>, accessed 8 March 2026.
54. UN Security Council, 'Qadhafi Chad: Interference, Occupation, Aggression', S/19400, January 1988, <https://digitallibrary.un.org/record/153475/files/S_19400-EN.pdf>, accessed 24 January 2025.
55. CIA, Directorate of Intelligence, 'Libyan Position and US Opportunities in Chad', declassified cable, 30 December 1986, <https://www.cia.gov/readingroom/docs/CIA-RDP86T01017R000808030001-1.pdf>, accessed 24 January 2025.

Advantage Over Time

A final consideration in how technological advantage manifests on the battlefield is that its effect is not consistent over time. War drives both adaptation and invention; unless a conflict is short, then it does not retain a fixed character.[56] For example, the Afghan Mujahideen in the 1980s began fighting the Soviet invasion with Lee Enfield rifles and, in some cases, paradigmatically obsolete Martini–Henry rifles, and navigated by starlight. They ended the war fielding FIM-19 Stinger MANPADS and MILAN anti-tank missiles.[57] The Soviets responded by dramatically increasing the firepower of infantry units, using high-altitude bombardments, and introduced new technology such as the TU-22 and the TOS-1 Buratino.[58] The fighting at the end of the conflict did not resemble – tactically or technologically – the fighting at the beginning.

The Battle of the Atlantic in the Second World War is a very pronounced manifestation of this phenomenon. When the German U-boat campaign began, the combination of well-made German submarines, secure communications, and an intelligence and reconnaissance structure to enable effective hunting gave the Germans technological advantage. However, the limitations of range, detection, coordination and offensive weapons were apparent. Moreover, the outcome of the campaign was potentially existential for Britain. These factors drove rapid technological adaptation among the Allies. The invention of decryption machines to decrypt Ultra, the introduction of improved radar and sonar, the mounting of more effective anti-submarine weaponry such as the hedgehog, the construction of fast escorts and then escort carriers, and the improvements in range of Allied aircraft all obviated the U-boat's initial technological advantages, such that the hunter eventually became the hunted. German technology did not remain static. The Third Reich continued to build ever-larger and more sophisticated submarines. However, while the technology continued to improve, the advantage that improvement offered diminished over time as the Allies built a system of technologies that were optimised against the U-boat problem.[59]

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56. The Clausewitzian dictum that the nature of war is immutable although its character changes is too often seen as an attribute that changes between wars or periods, but rarely within them, although this is clearly the case. See Carl Von Clausewitz, *On War*, edited and translated by Michael Howard and Peter Paret (Princeton, NJ: Princeton University Press, 1984).
57. Ali Ahmad Jalali and Lester W Grau, 'The Other Side of the Mountain: Afghan Mujahideen Tactics in the Soviet-Afghan War', US Marine Corps Studies and Analysis Division, 1987, <https://apps.dtic.mil/sti/tr/pdf/ADA376862.pdf>, accessed 4 February 2026.
58. Richard Mackenzie, 'The Afghan War', *Air & Space Forces Magazine*, 1 September 1988, <https://www.airandspaceforces.com/article/0988afghan/>, accessed 1 April 2026. See also Thomas Withington, 'The Experiences of the Soviet Air Force Afghanistan 1979-1989', *Air and Space Power Review* (Vol. 8, No. 1, Spring 2005), pp. 115–28. For history of the TOS-1, see Sebastien Roblin, 'TOS-1: This Russian Rocket Launcher Can Devastate Cities', *National Interest*, 22 April 2021, <https://nationalinterest.org/blog/reboot/tos-1-russian-rocket-launcher-can-devastate-cities-183296>, accessed 29 January 2026.
59. For an excellent description of this process, see Paul Kennedy, *Engineers of Victory: The Problem Solvers Who Turned the Tide in the Second World War* (London: Allen Lane, 2013), ch. 1.

When examining technological advantage, therefore, it is important to factor in an assessment of how long that advantage will endure.

A persistent lesson on technological advantage is that its impact diminishes over time even without enemy technological development, although it is likely that advantage will reach a floor in its depreciation. This was heavily emphasised by Guderian in his analysis of technological advantage in the First World War – the drip feeding of new capabilities into the front reduced their effect.[60] The enemy adapted and began working on countermeasures before it was possible to get the greatest impact from the system. This observation has been consistent. In 1991, Coalition airpower was decisive in reconnaissance and strike against Saddam Hussein's Iraq.[61] Subsequent air campaigns in the Balkans with similar technology, however, proved far less effective. Not only did Serbian air defences continue to contest NATO airpower, but the efficacy of allied bombing was severely limited by rudimentary, although competent, countermeasures.[62] Coalition airpower had not become significantly more or less advanced between the two conflicts, and the Serbs had not developed any major technological innovations that were unavailable to the Iraqis. But beyond better Serbian training, the Coalition had revealed what its technology could do. Doing so, therefore, gave the Serbs the information necessary to mitigate the advantages derived from it. The advantage was not eliminated, but it was diminished. Importantly, this diminution of efficacy can happen both within and between wars.

In summary, while a disparity in technology can be easy to identify, understanding the 'advantage' derived from it is often difficult. Technological advantage must be examined alongside other critical factors such as terrain, the competence of the users, the coherence of the system for exploiting the technological potential of the system, and the adversary's understanding of the capability and its limitations. Moreover, there is a critical relationship between a perceived or real technological advantage and the psychological impact on both troops and commanders. It is often toxic for morale if troops believe they are overmatched. For commanders, whereas a specific and discrete enemy technological advantage can be mitigated through planning, an unknown or theoretical advantage must nevertheless be planned for. This constrains options and adds uncertainty into a force's planning process. Finally, even in assessing the advantage derived from the technology itself, it is necessary to evaluate the scale of advantage conferred, the type – whether it is conferred by mere platforms or by a system of capabilities – and the realistic endurance of the advantage.

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60. Heinz Guderian, *Achtung Panzer! The Development of Tank Warfare* (London: Cassell, 1999).
61. James A Winnefeld, Preston Niblack and Dana L Johnson, *A League of Airmen: U.S. Air Power in the Gulf War* (Santa Monica, CA: RAND, 1994).
62. Benjamin S Lambeth, *NATO's Air War for Kosovo: A Strategic and Operational Assessment* (Santa Monica, CA: RAND, 2001).

Fighting from a Position of Technological Disadvantage

This chapter examines successful strategies for overcoming enemy technological advantage. Historical analysis shows that when a force secures victory from a position of technological disadvantage, it has required trade-offs – described below – that would be highly unpalatable to commanders and publics if they were the result of choice rather than being imposed by the enemy. While the UK may be able to overcome enemy technological advantage on the battlefield, it should not be complacent about the consequences of fighting under such conditions.

The Questions of Mass and Casualty Tolerance

A common way forces have mitigated technological disadvantage is fielding a greater mass of troops and accepting higher casualties than the enemy. In the examples cited from the Anglo-Zulu War, Normandy and Vietnam, victory was achieved by the technologically inferior side by fielding a much larger force. However, this was at the cost of a very unfavourable casualty exchange ratio. In Operation *Goodwood*, Allied tank losses were about four times those of German losses.[63] The disparity in firepower in Vietnam saw similar casualty exchange ratios. When US Marines departed their demilitarised zone positions in 1969, 1,419 had been killed.[64] This contrasts with about 7,500 NVA personnel, a casualty exchange ratio of just over 1:5. Technological

63. Dunphie provides an upper estimate of 400 Allied tanks. Irreparable vehicles may have been lower at 140, twice that of German tank losses. See Dunphie, *The Pendulum of Battle*, p. 79; Michael Reynolds claims 77 German tank losses. See Michael Reynolds, *Steel Inferno: I SS Panzer Corps in Normandy* (Barnsley: Pen & Sword, 2009), p.187.
64. Don North, 'A Little Piece of Hell', *New York Times*, 4 July 2017.

advantage, platform-for-platform, is of limited relevance if a capability is not available in sufficient numbers.

Mass is an enduring principle of war which cannot be easily obviated by tactical excellence. In the battle for the Golan Heights in 1973, for example, Israeli forces were far more tactically proficient than their more numerous Syrian counterparts and had excellent gunnery and tactical positioning, yet suffered high losses. Syrian forces culminated close to the point of Israeli exhaustion, with thin reserve forces remaining on the Israeli side.[65] The Israel Defense Forces then benefited from the US Operation *Nickel Grass* to reconstitute its forces during the Yom-Kippur War, mitigating the felt impact of enemy mass on the materiel degradation of Israeli forces.[66]

For the purposes of this paper, the use of mass and acceptance of high casualties as a means of compensating for technological disadvantage is discounted as a viable course of action for the UK. While even a minority of European states, working together, could prevail in an attritional struggle with Russia in purely demographic terms, such a policy is neither necessary nor politically acceptable. Fortunately, there are other approaches to overcoming technological disadvantage that do not rely on the acceptance of unfavourable rates of attrition. This chapter focuses on these. Nevertheless, as a wealthy state with a large network of allies, the UK can consider generating technological mass in conflict, even if it lacks a technological advantage over adversary systems.

Obviating the Logic of Enemy Advantages

The most important mitigation in dealing with an enemy technological advantage is to assess how it functions and then to adopt tactics that undermine the logic of its employment. A common example is the use of dispersion to obviate an enemy advantage in firepower. This has even been attempted to mitigate the threat of tactical nuclear weapons. For example, the 1950s US Pentomic Division structure was designed to survive the nuclear battlefield by emphasising mobility, extreme dispersal, light-strike capability organic to subunits and rapid convergence to achieve breakthroughs or defensive actions.[67] The theory was that if the force were properly dispersed, it would be prohibitively inefficient to effectively target with tactical nuclear weapons.[68]

65. Rohit Singh, 'The Battle for the Golan Heights', *Scholar Warrior* (Autumn 2011).
66. Chris J Krisinger, 'Operation Nickel Grass: Airlift in Support of National Policy', *Airpower Journal* (Vol. 3, No. 1, Spring 1989), pp. 16–28.
67. Lee Kichen, 'America's Atomic Army of the 1950's and the Pentomic Division', Army Historical Foundation, <https://armyhistory.org/americas-atomic-army-of-the-1950s-and-the-pentomic-division/>, accessed 24 January 2026.
68. US Army Transportation Corps, '9th Transportation Battalion (Pentomic) Unit History', <https://transportation.army.mil/history/unit_history/9tb.html>, accessed 24 January 2026.

Once concentrated and on the line of contact, such weapons would become counterproductive due to high friendly casualties.

The British Army of the Rhine had similar concerns about the effect of enemy conventional fires, responding with extensive use of passive defences. The British Army expected 10 Warsaw Pact artillery battalions to support each regiment on the offensive. Given this, digging in rapidly became vital, with extensive use of camouflage netting. Compared with the Pentomic mobility-dispersal paradigm, a premium was placed on passively mitigating Soviet reconnaissance and fires by hardening the force.[69] Both approaches, however, were aimed at minimising the impact of an area of enemy technological advantage.

Planning to disrupt the logic of an enemy advantage also works in the air and maritime domains. In the air domain, Russia has long appreciated that it has not remained competitive with US technology. In a direct contest of airpower, the VKS would be rapidly defeated. However, Russia has invested heavily in air defence systems. In the first instance, these are to hold NATO aircraft at reach by threatening its tankers and support assets. In the second instance, they can shoot down a wide range of NATO air-launched stand-off munitions, significantly degrading the efficiency of NATO air strikes.[70] Russian air defences do not offer competitiveness in the air domain and are far from impervious. However, by persistently being able to disrupt the efficient employment of airpower, Russia hopes to complicate and deny the advantages otherwise afforded by NATO's technological advantages in the air. While it may be the case that NATO air forces can develop tactics and techniques to overcome these defences, it should also be noted that the massive investment required to unlock the potential advantage offered by the air domain necessarily diverts resources from other priorities, increasing Rusia's room for manoeuvre elsewhere.

In the maritime domain, Ukraine has undertaken targeted investment to disrupt the significant technological advantages of the Russian Black Sea Fleet. Russia began the war with attack submarines, maritime patrol, guided missile ships of various classes, and amphibious assault platforms, while Ukraine had no vessels. In response, Ukraine began to employ uncrewed surface vessels (USVs) to harass the Russian fleet. It would be incorrect to argue that Ukraine's USVs represented a technological advantage. The constituent technologies involved were available to the Russians and indeed the Russians rapidly built USVs of their own. While older, less capable, Russian naval assets were destroyed by USVs, capital ships with proper watches and functioning sensors could effectively defeat them. However, to maintain a blockade against Ukraine, it was necessary for Russia to keep the sea, thereby extending the period at

69. Jim Storr, *Battlegroup! The Lessons of the Unfought Battles of the Cold War* (Warwick: Helion & Company, 2021), p. 188.
70. Jack Watling et al., 'Disrupting Russian Air Defence Production: Reclaiming the Sky', *RUSI Research Papers* (December 2025), <https://www.rusi.org/explore-our-research/publications/research-papers/disrupting-russian-air-defence-production-reclaiming-sky>, accessed 30 March 2026.

which the country's assets were under threat. Moreover, if Russia wished to strike Ukrainian shipping, it would open the potential for the USVs to target its own merchant fleet, which lacked the defensive systems of its navy. Thus, Ukraine was able to exploit how Russia's blockade was leveraging advantage from its maritime forces – and use it to target Russia's ships. To be sure, in the cases of both Russia's focus on dense air defence and Ukraine's focus on USVs, the technologies employed do not offer the breadth of options of a competitive air force or navy. Yet their focus has imposed serious dilemmas on opposing forces. Thus, targeting investment to weaken the foundation of the technical advantage an adversary derives from a capability can enable operational success.

Structuring Engagements

Another successful approach to mitigating enemy technological advantage has been to structure an engagement such that it is exceedingly difficult for the adversary to bring that advantage to bear. Consider air combat during the 1982 Falklands War. Argentina's air force was the most potent component of its forces in the Falklands campaign. The Argentine air force had competent pilots and modern and effective aircraft and munitions. In combat, the Argentines demonstrated a will to fight, as well as tactical and technical competence, and scored many hits on the British Task Force. Indeed, they had superior stand-off anti-ship capabilities than the British air component and were more effective in delivering air strikes than the British Harrier force. If they had not suffered from fuzing issues with their bombs, it is possible that they would have achieved the operational defeat of the British forces.[71] The Argentine air force's technological advantage in the anti-ship and ground-attack functions were also complemented by some distinct advantages in air-to-air engagements. Argentina's Mirage IIIEA and IIIDA were dedicated interceptors that could use their speed and altitude advantages to choose when to engage the British Harriers. In several dogfights, this allowed them to get behind Harriers at close range, threatening them with air-to-air missiles.[72] In a direct comparison, the Harriers were arguably at a slight disadvantage compared with some of their Argentine opponents, despite the British aircraft being equipped with superior missiles.

71. Pollack, *Armies of Sand*, pp. 221–23.
72. Hush-Kit Aviation World, 'Interview with Commander "Sharkey" Ward, Part 1: Sea Harrier FRS Mk 1 & Air Combat', 23 May 2020, <https://hushkit.net/2020/05/23/interview-with-commander-sharkey-ward-part-1-sea-harrier-frs-mk-1-air-combat/>, accessed 6 March 2026.

The British Task Force could have sought sea control, then control of the air, aggressively degrading Argentina's air force to isolate the Falklands before a ground invasion. Instead, the Task Force kept significantly east of the islands and used its combat air patrols as a defensive means of disrupting Argentine attempts to attack British ships. The result was that Argentine aircraft were operating at the limits of their range. Thus, whatever the technological balance, when Harriers engaged Argentine aircraft, the latter often broke off the engagement rather than dogfighting. The result was that what could have been a very dangerous set of engagements for the British Harrier force often saw the Argentines simply try to escape. This led to a lopsided loss rate of 23:0 in air-to-air engagements. Argentina's potential advantages in the air were therefore obviated by distance, such that it could never bring those advantages to bear.[73]

This structuring of engagements by choosing where to fight is a common tactic for ground forces facing technological disadvantage. For instance, drawing the enemy into urban terrain has become a favourite technique of insurgencies.[74] In Chad's campaign against Libya, discussed earlier, Chadian forces effectively goaded their opponents into dispersing from forward operating bases and pursuing their units into complex terrain. Doing so obviated Libya's advantages in firepower and ISR and brought about several victories at Wadi Doum and Fada. Rather than attempting a single, large battle, the Chadians engaged the Libyans piecemeal,[75] such that a 5,000-strong defensive position with armour could be whittled down.[76]

While in the Falklands and in Chad, an enemy's technological disadvantage was mitigated by dispersing the enemy and using distance to constrain its advantages, there are also many examples where engagements have been structured to limit the efficacy of fire by hugging the opponent. The approach was well explained by a Polish officer describing brief tactical gains against German forces in the early weeks of the invasion in 1939, although it represented a tactical, rather than an operational, success.[77] At the Battle of Mokra, Polish forces engaged scores of Panzer I and II tanks, despite lacking armour or anti-tank guns that could quickly traverse to engage the moving targets. But, in restricted terrain, the Panzer IIs could not benefit from the 600-metre engagement range of their guns and suffered significant losses to Polish Wz.35 Uruguayan anti-tank rifles, which could penetrate the 15-mm armour of the German tanks. German forces were pushed back with 500 casualties and a loss of 100 vehicles, for similar Polish losses in infantry. At Jordanów, Polish forces also held

73. John Shields, *Air Power in the Falklands Conflict: An Operational Level Insight into Air Warfare in the South Atlantic* (London: Air World, 2021); Sharkey Ward, *Sea Harrier over the Falklands* (London: Weidenfeld & Nicolson, 1992).
74. As predicted in David Kilcullen, *Out of the Mountains: The Coming Age of the Urban Guerrilla* (London: Hurst, 2013).
75. Bernard E Trainor, 'Desert Tactics of Chadians Like Old West', *New York Times*, 5 April 1987.
76. Brooke, 'Modern Arms a Key Factor in Chadian Gains'.
77. Hargreaves, *Blitzkrieg Unleashed*, p. 265.

back a large German force for two days. Colonel Stanislaw Maczek of the 10th Polish Motorised Cavalry 'Black Brigade' explained Polish tactics which, in his view, were effective:

> Engage the enemy in terrain with only close-range horizons, drawing the enemy into ravines and defiles, where he will not be able to open up his ranks without wasting too much valuable time; into narrows where he will be forced to fight with his fingers rather than his fist. To gain additional time and force his respect, continually seek opportunities to 'bite back' with brief forays or counterstrikes, thus forcing the enemy into time consuming cautiousness or exposing him repeatedly to surprises which will not expedite his advance.[78]

An important point about structuring engagements is that it only succeeds when the force lacking technological advantage takes the initiative. While non-state actors have raised the cost of an attack by retreating into complex terrain, they rarely end up successfully holding it.[79] Operational success is achieved where the defender has a plan to exploit the structured engagement it has created. This leads to a consistent trend. To win outright, the force that is at a technological disadvantage must seek the initiative.

Initiative and Intelligence

During the 1967 Six-Day War, Israel was not only outnumbered by Egypt, Jordan and Syria, but arguably also faced an enemy with several technological advantages. The Mystère and Super Mystère aircraft of the Israeli air force were inferior to the MiG-21s that made up the backbone of its opponent's fleets, while Israel's Mirage IIIC was comparable to, but had few advantages over, its numerically superior adversary. Israeli ground forces, meanwhile, fielded Second World War-era platforms, including upgraded Shermans, while their opponents had more modern and, in many respects, more capable armour. The tactical ineptitude of the Egyptian military complicates the discussion of Israeli mitigation of these advantages. But with Operation *Focus*, the level of Egypt's competence did not affect the outcome: the Israelis pre-emptively struck the Egyptian air force, mitigating any technological disparity faced by the Israeli air force in subsequent days by destroying the bulk of Egyptian airpower on the ground.[80]

78. *Ibid.*, p. 91.
79. There has been considerable debate over the effectiveness of structuring engagement in urban terrain. In most modern engagements, defenders who suffer significant technological overmatch (the First Battle of Hue, the Second Battle of Grozny, the Second Battle of Fallujah, the Battle of Mosul and the Battle of Marawi) are soundly defeated or whittled down as a fighting force, as in Gaza. See also Anthony King, 'Urban is Not Exceptional: A Response', Wavell Room, 28 April 2023, <https://wavellroom.com/2023/04/28/urban-is-not-exceptional-a-response/>, accessed 30 January 2026.
80. Michael B Oren, *Six Days of War: June 1967 and the Making of the Modern Middle East* (London: Penguin, 2003).

The attack on Pearl Harbor in 1941 could be seen as an unsuccessful attempt by Japan to achieve a similar effect. The sudden destruction of key enemy naval capabilities would have theoretically obviated Japan's industrial and technological position, which was weaker than that of the US.[81] Ultimately, the attack on Pearl Harbor failed to destroy the US carrier force. Had it done so, the war in the Pacific might have developed quite differently, allowing Japan to retain the initiative at sea. Instead, Japan and the US entered a high-stakes battle for sea control. The US won this at Midway where years of US investment in ship-borne radar gave the US a critical technological advantage over the Japanese fleet,[82] paving the way for US industrial might to overwhelm Japan's forces.[83]

Returning to Chad, Idris Deby, commander of Chad's forces in 1986, believed in bold, high-speed raiding, converging light-strike elements on Libyan columns from multiple directions. These high-speed attacks evoked British tactics in early engagements with the Afrika Korps in the Second World War, where converging elements would seek to close to an effective range, exploiting periods of low visibility, and mitigating the advantages of the German armour.[84] When this tactic failed, British casualties were often steep and German forces often baited pursuing British tanks into ambushes.[85]

The tactics outlined above, however, also rely on the fog of war. If an adversary has sufficient ISR and can bring it to bear, then it is very difficult to carry out such manoeuvres successfully. Exercising initiative successfully relies on having timely intelligence and denying it to the enemy. The lesson is clear: there is disproportionate value in remaining technologically competitive in ISR and counter-ISR capabilities. If an adversary enjoys sensor dominance and has a robust functioning C2 system, it is much harder to mitigate other areas of technological advantage. Thus, this is one area that should be prioritised when thinking about where to pursue technological advantage and where advantage may be ceded. The reconnaissance and counter-reconnaissance battles are likely to fundamentally shape future engagements in all domains.

In summary, approaches to succeed under conditions of technological disadvantage include building up a numerical advantage over the adversary, focused investment to unpick the logic of what gives an adversary advantage, the structuring of engagements to prevent an enemy bringing its technological advantage to bear, and the maintenance of the initiative, crucial to which is an effective means of gaining intelligence while denying it to the enemy.

81. Michael A Barnhart, *Japan Prepares for Total War: The Search for Economic Security, 1919–1941* (Ithaca, NY: Cornell University Press, 1988).
82. Malcolm A LeCompte, 'Radar and the Air Battles of Midway', *Naval History* (Vol. 6, No. 2, 1992).
83. Lars Celander, *How Carriers Fought: Carrier Operations in WWII* (Oxford: Casemate, 2018), pp. 134–44.
84. Patrick Delaforce, *Battles with Panzers: Monty's Tank Battalions 1 RTR & 2 RTR at War* (Stroud: Amberley, 2010), p. 190.
85. Barrie Pitt, *Wavell's Command: Crucible of War Book 1* (London: Cassell, 1980), p. 300.

A UK Approach to Mitigating Technological Disadvantage

Having identified how technological advantage manifests on the battlefield and the approaches states have taken to operationally overcome adversaries, despite technological disadvantage, this chapter examines how the UK may plan for a future in which it confronts adversaries with technological advantages. This chapter first considers how this situation may arise and then what the UK might prioritise to mitigate the consequences if such an eventuality cannot be avoided.

The Plausibility of the UK Ceding Technological Advantage

It may be asked how the UK may find itself at a significant technological disadvantage. After all, the country has advanced design and manufacturing capabilities and world-leading technologies in several military and dual-use fields, and participates in an alliance whose members are among the most technologically sophisticated states on the planet. However, there are several reasons why it may face significant technological disadvantage.

First, despite continuing ground-breaking research at UK universities, the UK has not modernised its forces relative to its adversaries. The UK has technologies that can improve its military systems, but the MoD has not contracted them to be turned into capabilities. In contrast, Russia's war in Ukraine has been maintained by sustained large-scale investment into both weapons production and R&D.[86] In terms of purchasing power parity, Russia spends approximately $500 billion on defence

86. Watling and Danylyuk, 'Winning the Industrial War'.

annually.[87] The result is that many Russian capabilities have been substantially improved. Navigational systems on Russian missiles have been hardened against electronic warfare and they have had countermeasures and penetration aides added to them that are optimised against current Western equipment.[88] In the UK, by contrast, the war has driven a resumption of the production of legacy systems such as Storm Shadow and Starstreak without upgrades.[89] And as the Russians have gained experience in engaging Storm Shadow, they have become more proficient at shooting it down and attuned their radar to its signature. The efficacy of these systems – which were not initially plentiful in inventories – is therefore declining. Thus, the UK may have the technology, but it has not invested to derive advantage from it.

Second, the UK currently introduces new technologies at a small scale. Even where it brings a new capability into service – such as DragonFire[90] – an advantage can only be gained if enough units are produced and fielded to shape how the force fights. Without passing a critical threshold of production volume, the force may have the technology but not derive advantage from it. The UK has munitions that can counter Russian air defences, such as Spear-3, but it has not scaled production of the munition or integrated it onto its aircraft. Adversaries, by contrast, are accelerating placing new capabilities into serial production such that they can deploy and therefore gain battlefield advantage from emerging capabilities.

Third, the UK is failing to assure its supply chains. The UK has learned the lessons from Ukraine on the use of UAVs and theoretically has the data to build structures that are competitive with the Russians in this area. Tactical UAVs, however, require advanced semiconductors, batteries and brushless motors. Europe lacks advanced semiconductor manufacturing and is largely dependent on Taiwan and Korea. For batteries and the permanent magnets needed to make brushless motors, Europe is dependent on China, including for critical raw earth minerals and their refining. Brushless motors are proving increasingly versatile, used on multiple categories of one-way attack, air-interceptor and heavy-lift drones, and rely on the same neodymium

87. Julian Cooper, 'A Budget for a Fifth Year of War: Military Spending in Russia's Budget for 2026', SIPRI, No. 1 (March 2026). Note that SIPRI give the foreign exchange in dollars for spending, not PPP, which must be calculated separately from the roubles allocated in the budget.
88. Author observations of missile engagements and physical examination of Russian missiles throughout the war in Ukraine.
89. *Forces News*, 'Starstreak Manufacturer Thales Sees Weapons Production Double Due to Ukraine', 25 March 2024, <https://www.forcesnews.com/technology/weapons-and-kit/nlaw-and-starstreak-manufacturer-thales-sees-weapons-production-double>, accessed 24 January 2026; HM Government, 'New Storm Shadow and Missile Cooperation to Boost Jobs as UK and France Reboot Defence Relationship', press release, 9 July 2025, <https://www.gov.uk/government/news/new-storm-shadow-and-missile-cooperation-to-boost-jobs-as-uk-and-france-reboot-defence-relationship>, accessed 24 January 2026.
90. Royal Navy, '£316m Deal for Royal Navy's First Laser Weapon after Successful High-speed Drone Trials', 20 November 2025, <https://www.royalnavy.mod.uk/news/2025/november/20/20251120-dragonfire-trials>, accessed 24 January 2026.

iron boron magnets used in other aerospace applications.[91] It is conceivable that in a major conflict with Russia, the UK's access – but not Russia's – to Chinese components or exports from Taiwan would be compromised. Indeed, there is mounting evidence that China is prioritising Russian access to material for uncrewed aerial systems.[92] Thus, a British effort to dissimilarly re-arm (prioritising uncrewed systems, for example) or to rearm with conventional firepower might find itself seriously constrained, despite leading British capabilities in energy efficient microprocessor design, including for UAVs with machine vision, object recognition and autonomy.[93]

Finally, it should be noted that China is developing and building capabilities that are fundamentally different from those used by Russia or the UK. As these capabilities proliferate, it is possible that the UK will find itself facing opponents with weapons for which it lacks clear counters. For example, while the performance of a complex weapon (such as failure rates and ballistic accuracy) cannot be precisely known prior to use at scale, Europe has no equivalent weapons to China's growing range of advanced conventional and dual-use ballistic missiles. European countermeasures, in terms of interceptor production and counter-hypervelocity systems are not expected to mature before the mid-2030s.[94] In the air domain, China fields long-range air-to-air missiles with no currently operational US or European equivalent.[95] And Chinese capabilities are proliferating to the European theatre.[96] It is not inevitable that the UK cedes technological advantage to its adversaries. But it is plausible, so officers should consider how to prepare to fight under such conditions.

91. Robert Tollast, 'Drones: Decoupling Supply Chains from China', *RUSI Research Papers* (November 2025), <https://www.rusi.org/explore-our-research/publications/research-papers/drones-decoupling-supply-chains-china>, accessed 24 January 2026.
92. Anton Ponomarenko, 'Russia's Chinese-Enabled Drone Supply Network Is Remaking Warfare', *The Diplomat*, 20 December 2025, <https://thediplomat.com/2025/12/russias-chinese-enabled-drone-supply-network-is-remaking-warfare/>, accessed 1 April 2026.
93. *Business Weekly*, 'Arm at the Heart of Revolutionary Anglo-US AI Programme', 21 September 2025, <https://www.businessweekly.co.uk/posts/arm-at-the-heart-of-revolutionary-anglo-us-ai-programme>, accessed 6 February 2026.
94. Sidney E Dean, 'Hypersonic Weapon Interceptor Developments', European Security & Defence, 15 September 2025, <https://euro-sd.com/2025/09/articles/armament/46457/hypersonic-weapon-interceptor-developments/>, accessed 29 January 2026.
95. The US is soon expected to have a competitor, the AIM-260 JATM, to China's PL-15 missile. It has a claimed range of 200 km. See Carter Johnston, 'USA Approves First AIM-260A JATM Export to Australia', *Naval News*, 28 November 2025, <https://www.navalnews.com/naval-news/2025/11/usa-approves-first-aim-260a-jatm-export-to-australia/>, accessed 4 February 2026.
96. Elisabeth Gosselin-Malo, 'Serbia Completes Fielding of Chinese Air-Defense System', *Defense News*, 9 January 2025, <https://www.defensenews.com/global/europe/2025/01/09/serbia-completes-fielding-of-chinese-air-defense-system/>, accessed 8 March 2026.

Mitigating the Risk of Technological Disadvantage

If the UK is to prepare for the mitigations outlined in the second chapter, some clear priorities can be drawn for the MoD. First, there is a requirement to invest heavily in ISR and counter-reconnaissance capabilities. Through the Digital Targeting Web, the UK is arguably making progress in building the infrastructure to maximise the exploitation of its existing collection. A significant proportion of the depth of collection for the UK, however, is dependent on the US and there is a strong argument for the UK to expand its own means of collection. The number of UAV ISR orbits that the British Army can generate, for example, is increasing but still inadequate, while sovereign electronic warfare collection is limited. Counter-reconnaissance, meanwhile, is an area where the UK is woefully under-resourced, lacking hard-kill interceptors or significant electronic warfare. Nor is there a clear counter-reconnaissance doctrine for defeating hostile state-based observation or other capabilities.

Over a longer timeline, it is important that, in the field of ISR, the UK does not see adversaries develop paradigmatic technological advantages. The obvious line of consideration is quantum sensing, where the UK has leading research along with Canada, Norway and some other close partners. China is a major competitor. If just 10% of the $17.5-billion investment that China made into its National Venture Capital Guidance Fund (a fund focused on emerging technology) in 2025 was directed to quantum technologies, it would be 10 times the UK government investment in quantum technology for the same financial year.[97] Internationally, however, the picture is less skewed towards Beijing, highlighting an opportunity for strong international cooperation to ensure that the UK retains competitive capabilities.[98] A similar risk may arise from advanced computing. While the UK has significant AI capabilities and the MoD is pushing to see how it can be leveraged for military advantage, the UK lacks the energy or data infrastructure to ensure access to such capabilities in conflict. This, too, is an area where the UK should invest since advanced computing will be critical to leveraging future ISR and intelligence capabilities. This is an area where the UK may gain technological advantage or cede it, but the gap should not be allowed to grow to the point of overmatch.

97. Hideki Tomoshige and Phillip Singerman, 'Understanding China's Quest for Quantum Advancement', Center for Strategic and International Studies, January 2026, <https://www.csis.org/analysis/understanding-chinas-quest-quantum-advancement>, accessed 6 February 2026.
98. A good case study of international technology cooperation is the development of the cutting-edge semiconductor manufacturing process, extreme ultraviolet lithography. This involved several decades of international research, unmatched by China at scale. See John VerWey, 'Tracing the Emergence of Extreme Ultraviolet Lithography: Lessons for Identifying, Protecting, and Promoting the Next Emerging Technology', Center for Security and Emerging Technology, July 2024, <https://cset.georgetown.edu/publication/tracing-the-emergence-of-extreme-ultraviolet-lithography/>, accessed 6 February 2026.

For structuring engagements such that the UK is at an advantage, the foremost line of effort is the buffer afforded to the UK by its allies and partners. Fighting at reach, from the territory of allies, imposes costs on the UK in projecting force, but also spares the UK from being under direct threat. It allows the UK to take a risk on having a balanced force because it can prioritise what delivers greatest effect in the context of its alliances. It therefore follows that it is disproportionately valuable for the UK to invest capacity where it can be of greatest use to its allies, especially those that geographically separate the UK from its foremost threat – Russia – and those close to key trade routes. The Atlantic is the geographic direction in which the UK lacks such a buffer. So, the focus of its maritime flank must be premised on countering the areas of enemy advantage.

Another critical aspect of the UK's ability to structure engagements is the use of the Continuous At Sea Deterrent (CASD) to deter vertical escalation against the UK. This capability limits what adversaries are prepared to do to the UK and therefore buys space for the UK to conventionally escalate in defence of its allies, or to shape operations through unconventional warfare. Here, ensuring the technological survivability of the CASD and the assurance of the delivery system are investment priorities. However, it is not necessary for the UK to necessarily keep pace with adversary strike capability. As long as UK submarines are survivable and its missiles can overcome adversary ballistic missile defence, the CASD will favourably structure conflicts in which the UK participates.

Within the context of these structured engagements – at reach from allied territory except in the Atlantic, with escalation capped by the CASD – it is possible to reach some deductions on where the British military can obviate the basis of adversary advantage. In the maritime domain, where British forces must contend with an adversary whose missiles can, and would pose a threat to UK bases, the area of enemy technological advantage is its cruise missiles and thus its submarines that can launch them.[99] Anti-submarine warfare is the area where the UK must prioritise capability to undermine adversary technological advantages.

Within the air domain, the majority of European NATO's weight of fires is air delivered. Russia has significant technological advantages in ground-based fires, the destruction of which requires the UK and its allies to be able to penetrate defended airspace. The protection for Russia's joint fires arises from its ground-based air defences and thus the key to undermining the adversary's advantage in firepower is degrading its integrated air defence system. Here, the UK can take the initiative and be offensively minded because, unlike its core allies, it has structured the engagement to avoid facing a

99. Sidharth Kaushal et al., *Interactive Summary: The Balance of Power Between Russia and NATO in the Arctic and High North*, RUSI Whitehall Paper 100 (Abingdon: Taylor & Francis, 2022), <https://www.rusi.org/explore-our-research/publications/whitehall-papers/interactive-summary-balance-power-between-russia-and-nato-arctic-and-high-north>, accessed 30 March 2026.

comparable direct threat to the homeland. Thus, the suppression and destruction of enemy air defences through joint fires and the appropriate training for this capability is the core priority.[100]

A further principle outlined in the previous chapter is that forces that are at a technological disadvantage should be offensively minded and seek the initiative. The emphasis on 'lethality' within the British Army is thus positive, speaking to the aspiration that while the UK may not project large force packages, they should be supported by disproportionate firepower.[101]

Even fighting when overmatched, it is clear that firepower is disproportionately valuable in determining success. Here, the UK should therefore prioritise the regeneration of its fires and the introduction of new fires systems. Insofar as Russian manoeuvre forces depend heavily on their advantages in firepower to enable advances, efforts that focus on the ability to find and destroy enemy UAV operators, artillery pieces and resupply, and hunting multiple launch rocket systems are all ways of degrading Russia's way of fighting. Investing in firepower and ways to keep fires supplied would allow the British military to disproportionately assist its allies and obviate the logic of Russia's advantages.

100. Justin Bronk, 'The Case for Greater Mission Specialisation by NATO's European Air Forces', *RUSI Occasional Papers* (February 2025), <https://www.rusi.org/explore-our-research/publications/occasional-papers/case-greater-mission-specialisation-natos-european-air-forces>, accessed 8 March 2026.
101. RUSI, 'General Sir Roly Walker's Closing Keynote Address at RUSI Land Warfare Conference 2024', YouTube, 25 July 2024, <https://www.youtube.com/watch?v=rDIip1V5c5Y>, accessed 24 January 2026; Nick Reynolds and Jack Watling, 'Measuring Lethality: Army Combat Power and Force Design', RUSI Research Papers (April 2026), <https://www.rusi.org/explore-our-research/publications/research-papers/measuring-lethality-army-combat-power-and-force-design>, accessed 7 April 2026.

Conclusion

One of history's lessons is that to fight an opponent who has technological advantage is to risk suffering disproportionate casualties. If an adversary is competent in leveraging its advantages, it is likely that it is either more efficient or able to execute manoeuvres that cannot be replicated. Moreover, the size of the technological gap matters, with the costs incurred by disadvantage increasing non-linearly as it expands. There is always the possibility that better training mitigates the superior technical capabilities of an adversary. However, while this means British forces should be well trained, it does not mean that it can be assumed the enemy will not be.

While it is not desirable to cede technological advantage, it may be unavoidable, especially in some military classes of capability. It is therefore important that the British military conceptualises how it should operate in the face of such a situation. This paper has identified several approaches to this problem that have worked historically.

First, some technologies have a disproportionate impact because of their effect on a system rather than their performance in isolation. By targeting investment, a state that is ceding technological advantage in a number of fields can nevertheless be disproportionately effective by leveraging islands of technological excellence. This approach is particularly relevant to the UK because, while the country has struggled to improve its military capabilities, it has advanced technologies.

Second, technological advantage can be obviated by fighting in a manner that mitigates the enemy's ability to bring that advantage to bear. To do this, it is necessary to identify the logic of employment of an adversary capability and then to adopt measures that target dependencies of those systems. A state can also structure engagements such that the performance of an adversary's weapons is constrained. These constraints may be brought about through range or sustainment limitations or can be imposed politically, such as through alliances with intermediate countries or through imposing thresholds on escalation through deterrence.

Third, a force can bypass an adversary's technological advantage by seizing and maintaining the initiative. Being aggressive is disproportionately valuable. It allows the technologically inferior force to dictate the tempo, timing and location of engagements. Generally, however, this becomes disproportionately dangerous and hard to execute if the adversary's technological advantage is in the field of ISR. This is an area, therefore, where maintaining competitiveness is critical.

The principles outlined above should inform capability choices on which areas of technology must be prioritised. However, while the third chapter shows that the UK may treat the technologies focused on as core areas of investment, it does not presume that the country will fail to maintain technological advantages in a wider set of capabilities. Thus, if a force finds itself committed to conflict, a process of rationalisation on increasing the production of critical technologies will be an important early decision. While this will be heavily shaped by what is industrially feasible, it should also be based on how a force envisages itself fighting. Getting this calculation right requires that officers can think about the strategies outlined in this paper and how they can be applied. The challenge is therefore to have officers fighting and working within an alliance where, for much of their professional lives, they have enjoyed technological advantage, but to encourage them to imagine and plan on the basis that this is not the case. Instilling the appropriate mindset is a task for professional military education and exercises.

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