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Heavy Armoured Forces in Future Combined Arms Warfare

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Published in 2023 by the Royal United Services Institute for Defence and Security Studies.

RUSI Occasional Paper, December 2023. ISSN 2397-0286 (Online).

Cover Image: *Courtesy of MoD / Rebecca Brown / OGL 3.0*

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Executive Summary

The British Army is likely to be called on to engage in high-intensity warfighting at some stage in the future, and must be able to do so credibly in order to contribute to NATO's deterrent posture. Heavy armoured forces and main battle tanks will remain an important element of warfighting, and will therefore continue to occupy an important position in the British Army's Order of Battle. There have been concerns about the vulnerability and survivability of main battle tanks on the contemporary battlefield, as well as the ability of lighter forces backed up by ISTAR capabilities and indirect fires to create difficult operational problems for the enemy in high-intensity warfighting. However, heavy armoured forces – through their substantial combat power – ensure that a force can remain mobile while in direct contact with enemy forces, and as such heavy armour still has a valuable role to play on the battlefields of the future.

However, adaptations are necessary if heavy armoured forces are to remain relevant. This paper argues that the primary requirement is to implement a comparative shift away from protection and towards mobility. Secondary requirements are numerous, and include better use of deception and decoys to counter improved enemy ISTAR capabilities, and the potential integration of uncrewed ground vehicles to add situational awareness and defensive capabilities without increasing vehicles' weights (already problematically high). The British Army's heavy armoured forces will also need to relearn old lessons about logistics, sustainment, vehicle recovery and the reconstitution of armoured formations that have suffered a significant level of battlefield attrition. Finally, crew expertise matters, and will – as always – be essential for keeping vehicles in working order on operations and minimising the need for the concentration of vulnerable elements of the support apparatus such as forward repair facilities. Investment in the British Army's people should therefore not be overlooked in the heavy armour context.

Introduction

The ongoing Russo-Ukrainian War is the largest conventional land war in Europe since 1945. The conflict has registered high losses – many at the hands of new weapons – among the main battle tank (MBT) fleets of both sides,[1] and in this context a longstanding debate has regained prominence: what future does the MBT have on the battlefield or in the force structures of modern militaries? The debate has been one of the more controversial and divisive ones over the future of warfighting. Although tanks were pivotal to 20th century warfare, their utility was often questioned – even during the Cold War – in a way that the utility of other revolutionary technologies such as aviation and radio communications was not.[2]

Tanks were introduced in the First World War to reduce casualties and break the deadlock imposed by trench warfare,[3] notably in the Battle of Cambrai in 1917.[4] After experimentation and increasing adoption during the interwar period, the Second World War saw tanks become established as a mainstay in the European and North African theatres of operations. However, since 1945, their utility has routinely been questioned and discussed. Most – but not all – of these discussions have concluded that MBTs still retain utility, but nevertheless concerns (particularly about whether the role of tanks can survive when faced with new threats) are periodically revived by instances of high losses.[5]

This debate is hugely relevant to the UK defence establishment (and particularly the British Army) as it looks to overcome years of underinvestment in conventional capabilities. A major component of this paper, therefore, will be to identify the implications of the MBT's changing role for the British Army's force structure

1. Joe Barnes, 'Vladimir Putin's Elite "Bodyguards of Moscow" Unit Pulverized in Ukraine', *The Telegraph*, 13 September 2022; David Axe, 'A Hundred Wrecked Tanks in a Hundred Hours: Ukraine Guts Russia's Best Tank Army', *Forbes*, 13 September 2022.
2. A C I Gadsby, 'Do We Still Need Tanks?', *RUSI Journal* (Vol. 142, Issue 4, 1997), p. 17.
3. J F C Fuller, *Tanks in the Great War 1914–1918* (New York, NY: EP Dutton and Company, 1920), pp. xviii–xix; Robert H Larson, *The British Army and the Theory of Armoured Warfare, 1918–40* (London: Associated University Presses, 1984), p. 65.
4. Wilfred Miles, *Military Operations France and Belgium, 1917: The Battle of Cambrai. History of the Great War Based on Official Documents by Direction of the Historical Section of the Committee of Imperial Defence. III* (London: Imperial War Museum & Battery Press, 1991), p. 88.
5. David Johnson, 'The Tank is Dead: Long Live the Javelin, the Switchblade, the…?', *War On The Rocks*, 18 April 2022; Ben Connable, 'The Marines Got Rid of Their Tanks. Is Ukraine Making Them Look Smart, or Too Smart for Their Own Good?', *Real Clear Defense*, 28 March 2022; John Stone, *The Tank Debate: Armour and the Anglo-American Military Tradition* (Abingdon: Taylor & Francis, 2013); Gadsby, 'Do We Still Need Tanks?', pp. 17–22; Federico Borsari, 'The Tank's Death Has Been Exaggerated', *CEPA*, 24 June 2022, <https://cepa.org/article/the-tanks-death-has-been-exaggerated/>, accessed 20 June 2023; Ed Cumming, 'Is This the End of the Tank?', *The Telegraph*, 14 March 2022; Thomas A Rebuck, 'Subjective Thinking and the Relevancy of Heavy Armor in Modern Warfare', *Armor* (Vol. 121, No. 5, 2012), pp. 20–23.

if it is to have the capability to fight on future battlefields. In 2022, Chief of the General Staff General Sir Patrick Sanders declared that Operation *Mobilise* – to deter Russian aggression in Europe – was to be the British Army's priority. This will mean the acceleration of the Future Soldier modernisation programme, with the aim of restoring the British Army's ability to conduct mobile combined arms warfare.[6] While the strategy is explicit about having a positional character,[7] this is because it is largely focused on deterrence and as such will involve posturing.

However, for deterrence to work, it must be credible. Credibility requires not just a presentational force but the ability to warfight, and British warfighting doctrine is defined by the 'manoeuvrist approach' – doctrinal terminology for manoeuvre warfare. Manoeuvre and heavy armoured forces – both heavy armoured combat vehicles classed as MBTs and infantry fighting vehicles (IFVs) or armoured fighting vehicles (AFVs)[8] and the associated support and logistics vehicles and apparatus – are deeply interconnected. Heavy armoured forces are known for their ability to manoeuvre and for using their unique characteristics to maintain this ability, even against other heavy armoured forces, and have traditionally been able to remain mobile under heavy direct and indirect enemy fire, and to engage and destroy conventional ground forces (including other tanks). Heavy armoured forces, if they are well-trained and well-led, can also quickly reform after taking objectives, and then immediately exploit further opportunities to do the same again (although, as will be explored below, these characteristics are not absolute and may not be guaranteed in future). The key characteristics of heavy armoured forces can be summarised as mobility, firepower and protection – criteria against which individual vehicles are judged.[9]

These concerns about the continued viability of MBTs, coupled with the clear imperative for the British Army to retain its ability to credibly fight wars, provide the context for this study, which examines the fate of the MBT and heavy armoured forces within the British Army, based on a survey of the changes to combined arms warfare and of evolving British strategic policy. There is much at stake here: force structure changes and procurement decisions have long lead

6. Patrick Sanders, keynote speech at the RUSI Land Warfare Conference, London, 28 June 2022, <https://www.gov.uk/government/speeches/chief-the-general-staff-speech-at-rusi-land-warfare-conference>, accessed 15 September 2022.
7. *Ibid*.
8. The exact technical definitions of IFVs and AFVs are not universally agreed, but in general refer to armoured transport vehicles that can protect the personnel carried within so that they can be dismounted in support of MBTs, and which have weapons systems allowing them to provide fire support or otherwise function as combat vehicles in their own right. There may be variations in weight classes, drivetrain and whether these vehicles are wheeled or tracked. A flexible and holistic interpretation of what constitutes an IFV/AFV will be taken in this paper.
9. David E Johnson, Adam R Grissom and Olga Oliker, *In the Middle of the Fight: An Assessment of Medium-Armored Forces in Past Military Operations* (Santa Monica, CA: RAND, 2008), p. 5.

times and must be made early. Unpacking the debate about heavy armoured forces in sufficient depth to identify trade-offs and opportunities (and, indeed, dead-ends) is therefore essential if policymakers and military leaders are to reshape land forces so as to remain credible for future warfighting.

This study frames issues in broad terms in order to be as accessible and useful as possible to international military practitioners, academics, policymakers and observers from outside the British defence establishment, but is UK-focused and, where appropriate, explores inherently technical issues. Chapter I covers British policy in the context of strategic warfighting requirements. Chapter II analyses the basics of combat power and the characteristics of MBTs and heavy armoured vehicles in order to provide a baseline understanding of/guide to the underlying issues. Chapter III covers the challenges to the continued utility of heavy armoured forces and discusses what adaptations should be made to ensure that they remain viable in the context of the changing threat landscape and operational environment. The paper concludes with recommendations for the way ahead.

This is not an engineering study, and although engineering issues will be introduced or discussed where pertinent, some issues – for example, the adoption of remote turrets or rubberised tracks – may be left unaddressed where they do not have sufficient relevance for the tactical, operational or policy choices identified. As a primarily theoretical analysis of the nature of operations, the study relies on a mixture of approaches to address the questions outlined above: a survey of the existing literature; engagement with military practitioners; observations of military exercises; and fieldwork in relevant operational areas. Much of the utility of armour is reliant on enablers and supporting capabilities, as well as the coordination of different arms in combination: combined arms. Thus, parts of this study will discuss other systems, rather than focusing solely on tanks per se. This is essential, as the utility of MBTs/heavy armoured forces cannot be adequately addressed if that capability is examined in isolation. However, the primary focus will be MBTs, as the issues of combined arms integration and supporting capabilities are too broad to be addressed comprehensively here.

As will be outlined in Chapter I, this study is predicated on credible conventional deterrence and thus the ability to warfight on land as an important pillar of security. Although this is current British policy, it is not a universally advocated strategy, and may justifiably be questioned. The key variables that determine the validity of conventional deterrence include to what degree an adversary's activity is constrained by how it sees its options for escalation management, and whether it is actually deterred from crossing the threshold of conventional war. Only the latter question can be answered within the scope of this study, through the metric of credibility. Subordinate to this are questions of the flexibility of conventional forces. Arguably, conventional forces have utility across the spectrum of operations short of high-intensity war, and indeed it has sometimes even been argued that they are essential for these tasks due to the limited combat power of lighter forces.[10] Consequently this study will, as a secondary consideration, also briefly touch on the dual-utility of heavy armoured forces for expeditionary and sub-threshold operations, as the strategic questions left unaddressed by this study indicate that it is essential that heavy forces whose primary application is high-intensity war should have secondary utility or be adaptable to other lower-intensity forms of competition and conflict. In more practical terms, the fact that the UK's strategic imperatives and defence policy could change in the future means that these questions about utility, which affect force structure and procurement decisions for conventional forces, should not be omitted.

One final baseline assumption for this study is that the future of armoured warfare should not be predicated on a less-capable adversary employing its forces poorly. Russia, the declared adversary and primary threat to NATO, is in the process of depleting its conventional forces, which have also proved themselves to have been presentational – investment was dedicated to impressive-looking technical capabilities, while basic practicalities were ignored. Catastrophic political decisions in the Kremlin, aside from the overall strategic blunder of launching a full-scale invasion in the first place, led to the prioritisation of equipment procurement over reforming the Russian armed forces' system of logistics and sustainment, hierarchical command structure, training and education doctrine, and military culture. The failure to recognise the need for revolutionary organisational change has contributed to Russia's military failures, but the extent of the self-created disaster in Ukraine will inevitably prompt reflection. Russia is likely to learn and rebuild its capabilities, while remaining an adversary and European security threat for the foreseeable future. This long-term threat should not be underestimated.

10. Tony Ingesson, 'Trigger-Happy, Autonomous, and Disobedient: Nordbat 2 and Mission Command in Bosnia', *Strategy Bridge*, 20 September 2017, <https://thestrategybridge.org/the-bridge/2017/9/20/trigger-happy-autonomous-and-disobedient-nordbat-2-and-mission-command-in-bosnia>, accessed 1 May 2021; David E Johnson et al., *The U.S. Army and the Battle for Baghdad: Lessons Learned – And Still to Be Learned* (Santa Monica, CA: RAND, 2019), p. 139.

I. Warfighting as a Component of British Defence Policy

Although warfighting has returned to prominence for the British defence establishment, the progressive reduction of Britain's fleet of MBTs and heavy armoured vehicles over the past 14 years represents a cause for concern. The 2010 Strategic Defence and Security Review stated that heavy armoured forces, which were deemed to include the Challenger 2 and Warrior IFV force, and the supporting AS90 self-propelled artillery and Titan and Trojan engineering vehicles, would be reduced in number, albeit with sufficient numbers retained for high-end warfighting and maintaining the possibility of regenerating these capabilities should the situation demand it. However, the Review was agnostic about the divisional force structure and only specified the retention of a division headquarters under which brigades might be commanded.[11] The 2015 Strategic Defence and Security Review, meanwhile, committed explicitly to a warfighting division, stating that its ground combat component would comprise two armoured infantry battalions and two Strike Brigades. Although the armoured infantry brigades would continue to field Warrior and Challenger 2, the Strike Brigades, with their Ajax vehicles, indicated a shift towards comparatively lighter mechanised forces that would trade sheer combat power for increased strategic mobility.[12]

The 2021 Integrated Review likewise directed the British Army to become smaller and lighter.[13] Former Chief of the General Staff General Sir Nick Carter considered competition – the constant use of a blend of military and non-military tools by the UK's enemies and adversaries without breaching a threshold that might trigger a decisive military response – to be a higher priority than warfighting, and directed that concept/capability development and restructuring efforts should reflect this prioritisation.[14] This approach flipped older assumptions that

11. HM Government, *Securing Britain in an Age of Uncertainty: The Strategic Defence and Security Review*, Cm 7948 (London: The Stationery Office, 2010), pp. 4, 24.
12. HM Government, *National Security Strategy and Strategic Defence and Security Review 2015: A Secure and Prosperous United Kingdom*, Cm 9161 (London: The Stationery Office, 2015), pp. 31–32.
13. Ministry of Defence, *Defence in a Competitive Age*, CP 411 (London: The Stationery Office, March 2021).
14. Nick Carter, 'Chief of Defence Staff Speech RUSI Annual Lecture', RUSI, 20 December 2020, <https://www.gov.uk/government/speeches/chief-of-defence-staff-at-rusi-annual-lecture>, accessed 8 August 2021.

the Army's warfighting functions served as an insurance policy to be held at readiness, with warfighting formations being able to adapt to lower-intensity conflicts if required. Although counterintuitive, there was a certain rationale to this, as well as plenty of historical evidence suggesting that capabilities developed for low-intensity conflict could prove not only useful but transformational for high-end warfighting.[15]

Despite this clear direction of travel, the aforementioned elements of British defence policy have received significant criticism, with repeated controversies over whether plans have been realistic or affordable.[16] As for the higher strategic direction that such plans are intended to deliver against, the 2023 NATO Vilnius Summit did not include any detailed updates regarding the UK's direct contribution to the Alliance, and Paul Cornish has noted that the recent Integrated Review Refresh included 22 sub-strategies,[17] which therefore provides little guidance for subordinate parts of government about what to prioritise (given that resources and leverage are finite). While explicitly de-prioritising certain areas of policy can appear undiplomatic and incur a short-term political cost, the current failure to clearly prioritise has resulted in the members of the professional military community expressing increasingly divergent understandings of what is being asked of them. Some fundamental points about the Integrated Review therefore require examination. First and foremost, the Integrated Review Refresh, although it argues for a tilt, still privileges the Euro-Atlantic over the Indo-Pacific, and the land domain and Russia are seen as the most prominent arena and threat to the UK. In terms of alliances, NATO is 'the highest priority'.[18] While the Indo-Pacific and China receive a great deal of attention in their own right within the Integrated Review, this paper is predicated on the view that Indo-Pacific security is most efficiently supported by ensuring that European security is adequately addressed by European countries, such that lines of effort in the Indo-Pacific are not undermined by drawing excessively on the US capabilities required in that theatre.

15. Sharon Weinberger, *The Imagineers of War: The Untold Story of DARPA, the Pentagon Agency That Changed the World* (New York, NY: Vintage, 2017), pp. 6–7, 74–75, 144, 239–56, 214–17, 275, 287; Robert Doughty, *The Evolution of US Army Tactical Doctrine, 1946-76* (Fort Leavenworth, KS: Combat Studies Institute, 1979), pp. 40–43; Nick Reynolds, 'Learning Tactical and Operational Combat Lessons for High-End Warfighting from Counterinsurgency', *RUSI Journal* (Vol. 164, No. 7, 2019), pp. 42–53.
16. Commons Defence Select Committee, 'Gambling on "Efficiency": Defence Acquisition and Procurement: 3 – The Defence Equipment Plan', 14 December 2017, <https://publications.parliament.uk/pa/cm201719/cmselect/cmdfence/431/43106.htm>, accessed 10 March 2021; National Audit Office, *The Equipment Plan 2020-2030*, HC 1037 (London: 2021), p. 4.
17. Paul Cornish, *The UK Integrated Review Refresh 2023 – Everything Everywhere All at Once* (Beckington: Cityforum, 2023), pp. 5–6.
18. HM Government, *Integrated Review Refresh 2023: Responding to a More Contested and Volatile World*, CP 811 (London: The Stationery Office, 2023), p. 22.

Even with regard to European security, the Defence Command Paper outlines other capabilities that will be grown as a matter of priority. This is a different approach from other members of NATO. The French Army, for example, is aiming to restore its ability to conduct armoured warfare at corps level, and while many French units are light- or medium-weight, the eventual replacement of the Leclerc with another more modern MBT remains a key French defence policy aspiration.[19] The British Army will not experience the same regeneration for warfighting at scale, and its heavy armoured capabilities will not grow unless there is a fundamental shift in guidance; however, neither has the British Army been directed to shed this capability. The Future Soldier Guide issued in 2021 outlined the British Army's warfighting division, 3rd Division, as containing two Armoured Brigade Combat Teams equipped with Ajax, an upgraded Challenger 3 and Boxer, and a Deep Recce Strike Brigade Combat Team equipped, after restructuring, with a mixture of guided multiple launch rocket system (GMLRS) and AS90 fires capabilities and Ajax and Jackal 2 for reconnaissance.[20] And so although the structure and enabling capabilities of the British Army's warfighting component are shifting, it is clear that the British Army will retain its heavy armoured forces, exemplified by the Challenger series of MBT, for warfighting: a rare scenario to be sure, but one at the core of why the UK maintains its armed forces in the first place.

Despite the focus on warfighting, a competing priority that must be highlighted is that of expeditionary operations and limited conflict, and the role that heavy armoured forces can play in these contexts. The post-Cold War move away from conventional deterrence, during which heavy forces suffered from a degree of neglect, was part of a shifting paradigm that prompted a resurgence of interest in smaller conflicts dating back to Britain's colonial era. During the Cold War, there had been divergent imperatives: on the one hand, to resource conventional deterrence between superpower-backed alliances; and, on the other, to fight small wars in distant expeditionary conflicts, often colonial in nature. Both scenarios involved superpower and ideological competition, but manifested very differently in terms of the lower stakes involved in the expeditionary conflicts (at least for the Soviet and NATO participants). Previously, the problem was conceived of as how to use lighter, more agile, more politically engaged expeditionary forces when militaries were prioritising heavier European warfighting forces that were based more on maintaining the peace through deterrence. The prospect of a major war between superpowers was a frightening one, but also a scenario that was more easily comprehended by the military

19. Bertrand Toujouse, 'French Land Forces Chief: How France's Army is Transforming for the Modern Era', *Breaking Defense*, 25 May 2023; Michael Shurkin, 'Why the French Army Will Continue to Prioritize Quality Over Mass', *War On The Rocks*, 28 April 2023.
20. Ministry of Defence, *Future Soldier: Transforming the British Army* (London: The Stationery Office, 2021), pp. 53–66.

units that were committed to it. The debate re-emerged, supposedly new but echoing the same considerations that previous generations had grappled with: conventional deterrence versus grey-zone competition, with the split between heavy and light forces predicated upon deployability and sustainment.

Despite the traditional division of labour between heavy and light forces, therefore, a strong case has been made for the utility of heavy armoured forces even in such delicate missions as peace support.[21] In positive contrast to the shortcomings of Task Force Ranger in Mogadishu, for example, the Swedish-Danish-Norwegian heavy armoured battalion Nordbat 2 exemplified this utility in Bosnia in 1993 when it was able to provide decisive overmatch and retain freedom of movement, which in this case was essential to the UN mandate in their area of operations.[22] Canadian forces, too, found Leopard 2 MBTs to be invaluable tactically in the Afghanistan counterinsurgency campaign, despite having envisioned being able to make do with the 17-tonne wheeled Light Armoured Vehicle III (LAV III).[23]

Nevertheless, arguments in favour of the continued use of heavy armour outside of high-end warfighting are likely to fall victim to the financial and logistical challenges associated with deploying and sustaining heavy armour. Even for the best-resourced militaries, heavy armour is likely to be an unaffordable luxury except when facing a peer or near-peer conventional force. Likewise, for all the strong arguments that can be made in favour of Nordbat 2's deployment to Bosnia, it must be remembered that there were numerous peace support operations ongoing at the time, all of which could lay justifiable claim, on moral or humanitarian grounds, to receiving serious military resourcing from the international community. The realities of multiple conflicting demands and limited capacity mean that British heavy armoured forces will at best be committed sparingly to such future missions, if at all, as a secondary benefit of maintaining a warfighting force that might on occasion donate small force elements if able to do so. Their presence can help peacekeepers, policing missions, counterinsurgencies and stability operations to focus on their core missions more effectively (through tactical overmatch), thus removing the distraction of these missions getting bogged down in indecisive combat situations. This useful function of heavy armoured forces should not be overlooked.

The broad utility of heavy armoured forces across the spectrum of conflict – both their utility in their primary role, and as a hedge against future sub-threshold contingencies should the acute requirement for conventional deterrence in

21. Thomas Donnelly and Frederick W Kagan, *Ground Truth: The Future of U.S. Land Power* (Washington, DC: American Enterprise Institute, 2009), p. 52.
22. Ingesson, 'Trigger-Happy, Autonomous, and Disobedient'.
23. Howard Mark Anthony, 'Close Combat Vehicle and Leopard 2 Main Battle Tank: Back in the Heavyweight Fight', master's thesis, Canadian Forces College, 2012, pp. 58–75.

Europe decline in the long term – means that, from one perspective, the argument in favour of MBTs is clear-cut. Yet sceptical arguments about MBTs generally point to technological changes that compromise the ability of heavy armoured vehicles to maintain one or more of their three traditional characteristics – mobility, firepower and protection. Many of these concerns are valid, particularly those relating to pervasive UAV ISTAR, networked headquarters and forces, and precision fires able to strike large numbers of targets far from the frontline, which bodes poorly for forces that are either slow, easy to detect or require a large logistics tail. In this conception of the future, lighter ground forces will be more viable through a reduced signature, more operational mobility, and through their reduced cost allowing them to be generated in larger numbers, offsetting the enemy's ability to concentrate precision fires against an identifiable centre of mass. Implicit in this vision is that geographical concentration of forces in the attack will be difficult, meaning that units will have to fight dispersed for an increasing proportion of operations.

As will be discussed in Chapter III, this hypothetical conception of the future is not unchallenged and its precise implications are disputed.[24] Nevertheless, experimental evidence indicates that changes of one sort or another will be required for ground forces to remain effective,[25] with experience from Ukraine suggesting that alternatives to dispersion are to 'dig deep, or move fast'.[26] All three of these alternatives will likely play a role during different phases of operations and campaigns, but dispersion looks set to remain the prevalent approach, and several resulting adaptations to force composition and structures would in theory create a survivable, viable warfighting force. But it would be one that lacked combat power in the direct fight – that is, when engaging an enemy force within direct line-of-sight using weapons systems organic to the units employing them (whether supported by enabling indirect capabilities or not). The conflicting imperatives to disperse or concentrate forces pose difficult dilemmas that have yet to be conclusively resolved. The resolution of these questions requires an examination of exactly what MBTs bring to high-end combined arms warfighting – and it is to this that we turn next.

24. Stephen Biddle, 'Back in the Trenches: Why New Technology Hasn't Revolutionized Warfare in Ukraine', *Foreign Affairs*, 10 August 2023; T X Hammes, 'Game-changers: Implications of the Russo-Ukraine War for the Future of Ground Warfare', Atlantic Council, 3 April 2023, <https://www.atlanticcouncil.org/wp-content/uploads/2023/04/Game-Changers-or-Little-Change-Lessons-for-Land-War-in-Ukraine-.pdf>, accessed 10 August 2023.
25. Jack Watling, 'Lessons from Exercise Green Dagger', *RUSI Defence Systems*, 5 November 2021; Jack Watling, 'The Need for Speed in Confronting Peer Adversaries', *RUSI Defence Systems*, 28 October 2021.
26. Mykhaylo Zabrodskyi et al., 'Preliminary Lessons in Conventional Warfighting from Russia's Invasion of Ukraine: February–July 2022,' RUSI, 30 November 2022, pp. 62–63.

II. The Role of the MBT in Combined Arms Warfare

The theoretical underpinnings of combined arms warfare, though well established, are worth reiterating here. While heavy armoured forces have numerous applications, their primary purpose is warfighting – the application of violence in order to defeat an enemy. This requires combat power, traditionally understood to comprise three core elements: mobility; protection; and firepower.[27] Firepower is sometimes referred to as lethality or offensive power.[28] Mobility, protection and firepower have long been components of combat power in US Army doctrine, and provide a widely accepted theoretical framework. Leadership was sometimes considered to be an additional fourth component. In US doctrine, this model was expanded to eight components by 2017: 'leadership, information, mission command, movement and maneuver, intelligence, fires, sustainment, and protection',[29] a departure from the underlying principles that attempted to integrate disparate elements into the model. The result, at the risk of blurring what aspect of war was being described by the original model, nevertheless highlights the importance of supporting arms and integration.

This model of combat power is not directly replicated in British doctrine, but, where combat power is euphemistically referenced in the British Army's keystone ADP Land publication, it is seated within the physical component of fighting power.[30] The tactical functions of a combined arms force provide the best analogue to US doctrine: these are command, intelligence, outreach, information activities, fires, manoeuvre, protection and sustainment,[31] a valuable contrasting model in that it highlights the inevitable transition from warfighting to stability operations, even in the context of a warfighting campaign, in a way that US doctrine does not.[32]

27. Department of the Army, 'FM 100–5: Operations', 1993, pp. 2–9; Department of the Army, 'FM 3-0: Operations', 2017, pp. 2-22, 5-1.
28. Jonathan M House, *Combined Arms Warfare in the Twentieth Century* (Lawrence, KS: University of Kansas Press, 2001), pp. 6–7.
29. Department of the Army, 'FM 3-0', p. 2-22.
30. Ministry of Defence, 'ADP Land Operations: Part 2: The Application of Land Power', Land Warfare Centre, 2022, pp. 1–11.
31. Ministry of Defence, 'ADP Land Operations: Part 2', pp. 4-7–4-13.
32. On this subject, ADP Land is underpinned by Multi-Domain Integration. For more information, see Ministry of Defence, Development, Concepts and Doctrine Centre, 'Joint Concept Note 1/20: Multi-Domain Integration', 2020.

Other academic models can also be useful. For example, operability has been hypothesised by Yoo, Park and Choi as an alternative fourth function of combat power when considering the original triangular framework at the platform level;[33] the technical and tactical reasons for this will be discussed in a subsequent chapter. While operability might better be described as a cross-cutting attribute that helps deliver and sustain all forms of combat power, and the suggestion may be conceptually flawed, the importance of operability, logistics and sustainment should nevertheless be highlighted.

Understanding warfighting and combat power in terms of the original triangular framework of mobility, protection and firepower is useful, as it encourages thinking about how a force should function overall and deliver the required effects when conducting operations in the land domain. In particular, the triangular model is useful for identifying the core trade-offs that are inherent to different types of force, whereas augmented versions of the model include elements – for example, leadership and command and control – that are applicable regardless of the type of force being assembled, and which therefore do not usefully illustrate the trade-offs between heavy armoured forces (built around MBTs) and other lighter formations. However, as will be discussed, integration of other elements is essential to ensure the viability of heavy armoured forces, and so should not be discounted.

Ultimately, and regardless of which variation of the conceptual model of combat power is preferred, their value lies in countering the technological determinism that is prevalent in commentary on defence and security issues. While this determinism is often driven by an appreciation of technological capability, it can result in overestimations of the impact of technological change, or in a failure to understand the second- and third-order impacts of this change on other parts of a military system and on battlefield dynamics. All of the elements discussed above factor into effective combined arms warfare at some stage. Those forces that make warfighting their forte and can credibly fight wars at scale do so in large part due to combining arms, whereby a variety of different arms – artillery, infantry, armour, engineers, logistics, medical services and so on – act in concert. However, not all militaries can be considered combined arms forces, as this status is achieved only by mastering the simultaneous integration of capabilities to create the right synchronised effects to prevail in war, preferably decisively.[34]

33. Chul Yoo, Kang Park and Sang Yeong Choi, 'The Vulnerability Assessment of Ground Combat Vehicles Using Target Functional Modeling and FTA', *International Journal of Precision Engineering and Manufacturing* (Vol. 17, 2016), pp. 651–58.
34. House, *Combined Arms Warfare in the Twentieth Century*, pp. 4–5, 6–7; Stephen Biddle, *Military Power: Explaining Victory and Defeat in Modern Battle* (Princeton, NJ: Princeton University Press, 2004), p. 35.

Mobility, Firepower and Protection

Within this model, MBTs are not the only element of a force that delivers combat power. At a platform level, however, the original triangular concept of mobility, firepower and protection best encapsulates their value, for while they trade these characteristics off against each other (as does any type of platform), MBTs nevertheless embody all three in a unique, heightened manner. The way that armour operates at the platform level governs the broader tactical and operational dynamics when these vehicles are fielded at scale. A deeper understanding of armoured vehicles is therefore useful, as it explains why they have developed the characteristics that now typify them.

MBTs developed their current format in the interwar period: a tracked hull with an engine; an independently rotating turret; and a main armament. By the end of the Second World War, this configuration had been almost universally refined to eliminate features such as hull-mounted machine guns and had standardised the MBT crew at either three personnel – commander, gunner and driver (if an autoloader is used to reload the main gun) or four (if an extra crew member is added to load the main gun manually). Apart from the driver, most MBTs have all other personnel located in the turret and turret basket assembly.

Mobility is the most complex of the three characteristics that this configuration delivers. Although tracked vehicles are valued for their versatile mobility characteristics, MBTs and heavy armoured forces should not be described as the most mobile type of formation: rather, they are useful under certain circumstances. Physical terrain is not homogenous and so generalisations tend to be unreliable,[35] and light infantry can of course move through and fight in almost any environment impassable to other forces if given sufficient time (the obvious example being primary jungle). Restrictive terrain has – perhaps erroneously – been deemed unsuitable for armoured forces.[36] Tracked armoured vehicles can operate in most types of mountainous terrain except for alpine-like mountain ranges (where even light infantry would require technical rock-climbing skills to achieve full mobility) and the summit zones of interior and coastal mountain ranges.[37] However, outside of these extreme instances, it is broadly correct to say that tracked vehicles – which in military terms largely mean heavy armoured forces – are the most tactically mobile.[38]

35. J Y Wong, *Terramechanics and Off-Road Vehicle Engineering: Terrain Behaviour, Off-Road Vehicle Performance and Design*, 2nd Edition (Oxford: Butterworth-Heinemann, 2009), p. 8.
36. Dana J H Pittard, 'The Heavy Battalion Task Force in Mountainous Terrain: Are Current Tactics, Techniques, and Procedures Adequate?', master's thesis, School of Advanced Military Studies, US Army Command and General Staff College, 1994, p. 1.
37. Dana J H Pittard, *The Heavy Battalion Task Force in Mountainous Terrain*, pp. 2–3.
38. Wong, *Terramechanics and Off-Road Vehicle Engineering*, p. 16.

The technical reason for this is that the increased contact area of tracked vehicles' running gear generally gives them lower ground pressure than their wheeled counterparts, thus providing improved thrust and traction (even if the tracked vehicles are in absolute terms far heavier). Theoretically, this improved traction will be less pronounced on loose or frictional soil (such as sand) than on cohesive soil (for example mud or clay), but in practical terms the difference is limited.[39] Tracked vehicles are less likely to become bogged in or to slip, and can thus cross more difficult terrain than wheeled vehicles. Provided that ground is not so soft that vehicles start to sink, tracked armoured vehicles also have a significant advantage over light infantry, and if the ground is trafficable then their engine power means that they will be able to move much faster than dismounts.

Aside from the power of the engine and the design of the drivetrain, a major limitation on the off-road mobility of individual vehicles is the shearing effect between the tracks (or wheels) and the terrain, which causes a loss of traction and hampers vehicles' ability to cross ground.[40] Shearing is most likely to occur on steep slopes; traversing slopes is significantly more difficult than heading directly up ascents and down descents, and the consequences of a failed traverse are more likely to involve a roll-over.[41] With regard to clearance angles, the approach, departure and belly-clearance or ramp angles will also influence what obstacles a vehicle can climb over.[42] While wheeled vehicles are also good at traversing slopes, tracks have the advantage of being comparatively resilient to small arms fire and fragmentation from artillery, which have a tendency to shred rubber tyres and immobilise wheeled vehicles. This allows tracked vehicles to retain mobility even in the midst of heavy fighting, although this comes at the cost of increased mechanical complexity, with implications over longer distances that will be discussed shortly.

Hull shape and drivetrain design can give remarkable tactical mobility under the right circumstances. During the Korean War, British troops often marvelled at the ability of their Centurion MBTs to climb up slippery, muddy hills and to wade through flooded rice paddy fields.[43] Unfortunately, this kind of ability involves inherent trade-offs, and different designs within the same vehicle class and formal tactical role can exhibit markedly different performance. For example, a low number of road wheels grants sufficient tactical mobility while being mechanically simple, but the resulting high ground pressure degrades the ability to operate on soft ground. Likewise, tracked armour is excellent in mountainous

39. *Ibid.*, pp. 440–46.
40. *Ibid.*, pp. 115–53.
41. Tom Sheppard, *Four-by-four Driving*, 5th Edition (Hitchin: Desert Winds, 2019), pp. 4.16–4.19, 4.22–4.23.
42. *Ibid.*, pp. 3.8–3.9.
43. Andrew Salmon, *To the Last Round: The Epic British Stand on the Imjin River, Korea 1951* (London: Aurum, 2010), p. 100.

terrain up to a certain gradient, but where lighter tracked vehicles excel, heavier tracked armour might struggle, both because of tight mountain roads and generally constricted terrain, and due to the weight and ground pressure of the vehicles making steep slopes impossible to traverse. Most principles and techniques of off-road tactical mobility are transferable between wheeled and tracked vehicles, but tracked vehicles tend to be more forgiving.[44] Nevertheless, reading the ground and how to move across it is a skill, and tanks must still be driven carefully. With professional and well-trained operators, heavy armoured vehicles can cross difficult ground quickly, and push through many obstacles, in a way that other forces cannot. Likewise, the mobility advantage does not necessarily make wheeled or heavy tracked armour more suited to manoeuvre. In forest, jungle or mountainous terrain, armour may be better employed positionally due to the requirement for slow, careful movement, or by leveraging its high level of firepower and protection when forcing an enemy from key terrain, with manoeuvre derived from the employment of light infantry. It is first and foremost the environment and context that determine how heavy armour is employed. The employment of armour to enable manoeuvre is a product of geography first, and of the characteristics of the vehicles second.

Over long distances, wheeled forces may enjoy comparative advantage over heavy tracked armour if trafficable routes are available. Due to the simplicity of their running gear and drivetrains, wheeled vehicles require less maintenance and experience a far lower breakdown rate. They also require less fuel, and the reduced maintenance requirement in turn reduces the volume of spare parts, maintenance stores and recovery mechanics that need to accompany them. It has thus been argued that lighter wheeled vehicles provide better operational mobility when moving between positions, areas and objectives, an attribute that is written into the British Army's Strike Concept.[45] The truth is more complex: heavy armour is still able to move at pace over great operational distances, and can do so over worse ground, whereas wheeled armour, with its different mobility characteristics, remains competitive with its heavier counterparts at the operational level, depending on the environment.

Issues of strategic mobility also need to be considered. When driving into theatre or to a forward assembly area, MBTs and heavy armoured vehicles are carried on heavy equipment transporters (HETs) for substantial parts of the journey to reduce wear and tear on the drivetrain and running gear. Long road moves are often associated with a high rate of breakdowns if heavy armoured forces need

44. For more information about the physics and engineering of off-road vehicle performance, see Wong, *Terramechanics and Off-Road Vehicle Engineering*; for a readable practitioner's guide covering technical and tactical issues, albeit those focused on wheeled vehicles, see Sheppard, *Four-by-four Driving*.
45. Land Warfare Centre, 'Doctrine Note 21/01: The Strike Handbook, Draft Version 2.1, Part 1: An Introduction to Strike', October 2020, pp. 1-19–1-21.

to drive without support from HETs, and those vehicles that do arrive will still incur a higher maintenance burden. MBTs and heavy armoured vehicles can technically be airlifted into a given theatre, but only the largest transport aircraft are able to carry them, and cannot transport them in large numbers. Thus for large armoured formations to arrive in theatre quickly, an unattainably vast strategic airlift capability would be needed, as otherwise such a move would be impossible within any reasonable timeframe due to the number of trips that would be required. Access to runways of sufficient dimensions (and paved to a standard to safely accept heavy transport aircraft) is also a limiting factor. Sealift is the most efficient method of moving MBTs and heavy armoured vehicles over long distances and between theatres, but this requires time and safe ports at which to offload vehicles (unless a specialised amphibious landing capability for heavy armoured vehicles is also factored in). Railway transport is also efficient, but involves similar bottlenecks to airlift, this time with regard to rolling stock and available railheads.

All modes of long-distance transport for heavy vehicles still require practice if they are to be completed without unnecessary delays; no one should underestimate the inherent coordination challenge facing the combat units themselves, the logistics units supporting them and the organisations in charge of the infrastructure stemming from the distances involved and the transport volumes associated with large numbers of vehicles.[46] Consequently, the threat posed by heavy armour is most credible when it is either forward-based or reserved for use within an operational distance of its home base. Nevertheless, it should be noted that deployment of heavy armoured forces is possible, and that medium armoured forces, particularly those built around tracked armoured vehicles (regardless of whether they are of a lighter weight) also incur many of the same costs and constraints.

Protection is the one inherent attribute of heavy armoured forces that cannot be replicated by lighter combat vehicles. This protection traditionally came from large amounts of passive armour, either rolled homogenous steel or some form of composite material, which could deflect or absorb the energy from an incoming projectile. Passive armour can be angled, and is generally concentrated on the frontal aspect of vehicles in order to provide the best protection for the least weight. Some vehicles complement this arrangement with explosive reaction armour (ERA) blocks: boxes of explosives that detonate when struck with a sufficiently powerful projectile, dissipating the energy of the incoming projectile and reducing the likelihood of the armour being penetrated.

46. Matthew T Mosteiko, 'Deploying Armor: A Transportation Battalion's Perspective and Lessons-Learned', *Armor* (Vol. 138, No. 4, Fall 2021), pp. 39–42.

Passive armour has increasingly been enhanced by active protection systems, which can be split into 'hard kill' and 'soft kill' systems. Hard-kill systems physically shoot down incoming projectiles. For example, Rheinmetall's APS-Gen3 comprises short-range radars (which detect incoming projectiles on approach), electro-optical sensors (which locate projectiles immediately before impact) and an explosive countermeasure (which detonates to destroy the projectile) – this latter kinetic element could be described as a guided ERA block. Other systems, such as the Israeli-designed Trophy, fire their own shotgun-like munitions to intercept incoming projectiles.[47] Soft kill systems are more diverse, and encompass any system that interrupts the guidance systems of incoming projectiles or the systems from which they are launched or guided. Retro-reflective detection, laser warning receivers and defensive electronic warfare systems all aid in the detection of anti-tank weapons attempting to target the vehicle. In terms of defeating the anti-tank systems themselves, lasers may be used to dazzle electro-optical sensors, while radio frequency jamming may serve to disrupt command signals between a missile and its launcher. While the technologies/methodologies of different soft-kill systems vary, they are for the most part only relevant to defeating guided systems. The promise – and limitations – of technological developments in this area will be discussed in the next chapter.

In terms of firepower or lethality, modern MBTs remain one of the most potent platforms on the battlefield, particularly when focusing on direct line-of-sight or close-range engagements. This is due to the power of their main armament and their ability to carry other anti-tank weapons, all of which can quickly be brought to bear by virtue of being mounted in a stabilised turret. Jonathan House usefully split anti-tank weaponry into two categories – chemical energy weapons and kinetic energy weapons.[48] This distinction remains valid and applies equally to weaponry mounted on MBTs, or on lighter vehicles, or carried by dismounted infantry. Chemical energy weapons typically equate to anti-tank guided missiles (ATGMs), although long-ranged precision fires and loitering munitions technically fit within this bracket; as these weapons are generally employed within the anti-tank role performed by other forces (with limited use by MBTs themselves), they will be discussed in Chapter 3. While MBTs do not have a monopoly on lethality, the size of MBTs as a platform means that carrying anti-tank weapons does not require them to forsake mobility.

The kinetic energy weapons category essentially encompasses the main guns of MBTs, as self-propelled or towed anti-tank guns have been deemed tactically ineffective by most militaries, and man-portable anti-tank rifles are considered

47. Joseph Trevithick, 'German Firm Says it Has a "Safer" Way for Tanks to Blast Incoming Projectiles', *The Drive*, 23 January 2018, <https://www.thedrive.com/the-war-zone/17920/german-firm-says-it-has-a-safer-way-for-tanks-to-blast-incoming-projectiles>, accessed 27 October 2020.
48. House, *Combined Arms Warfare in the Twentieth Century*, pp. 142–44.

to be too low-powered to threaten all but the lightest modern armoured vehicles.[49] Whether of Western or Russian design, MBT main guns now generally fire armour-piercing fin-stabilised discarding sabot (APFSDS) rounds, the core penetrator dart being made from either depleted uranium or tungsten.[50] While other forms of munitions can be fired, other types of specialised anti-tank round such as high explosive anti-tank (HEAT) and high explosive squash head (HESH) are less effective against modern armour. If equipped with modern ammunition, the main gun remains a potent anti-armour weapon, with the added benefit of being comparatively light, quick to reload, and cheap.

MBT main guns have long been stabilised, allowing them to fire accurately on the move. This remains a significant engineering challenge,[51] putting established defence contractors who have mastered the manufacturing of stabilised guns at a distinct advantage to competitors. Most Western MBT main guns are of 120-mm calibre, which is the approximate maximum size for a main gun round that can be handled quickly by a human loader without mechanical assistance. Any significant increase in calibre would force Western heavy armour to swap the human loader for an autoloader: this would probably require the four-person crew of commander, gunner, loader and driver to be reduced by one, a move that is considered undesirable due to workflow issues both in the vehicle itself and in the field more generally. Were the fourth crew member to be retained alongside the autoloader, MBT turrets – which are already approaching practical size limits – would have to become even bigger. Given the trade-offs involved, and bar any unexpected technological advances in main gun technology, tank main guns are unlikely to significantly increase their lethality in the foreseeable future. Nevertheless, they remain potent, especially when factoring in the weight and rate of fire that an MBT can employ from its stock of onboard ammunition.

Overall, the ability of MBTs to quickly cross difficult terrain and obstacles, to quickly engage successive targets (including other MBTs) in their direct line-of-sight with a highly effective main gun, and their ability to absorb punishment and continue fighting unless targeted by dedicated anti-tank capabilities, make for a potent and flexible ground combat unit. While this comes at the cost of a higher logistics and sustainment framework to support them, MBTs' sheer combat power makes them uniquely capable not only of destroying other heavy armoured forces (if employed correctly), but of maintaining momentum while

49. Harry Yeide, *The Tank Killers: A History of America's World War II Tank Destroyer Force* (Havertown, PA: Casemate, 2013), pp. 205, 228–29, 250–51.
50. Michael Peck, 'Russia is Arming its Tanks with a Controversial New "Bullet"', *National Interest*, 24 December 2018, <https://nationalinterest.org/blog/buzz/russia-arming-its-tanks-controversial-new-bullet-39682>, accessed 20 April 2021.
51. Tolga Dursun, Fırat Büyükcivelek and Çağrıhan Utlu, 'A Review on the Gun Barrel Vibrations and Control for a Main Battle Tank', *Defence Technology* (Vol. 13, No. 5, October 2017), pp. 353–59.

doing so.[52] They are particularly useful, if properly employed and enabled, for offensive operations transitioning to breakthrough-and-exploitation.

In practical terms, breakthrough-and-exploitation corresponds to deep battle theory (or deep operations theory, in the parlance of its Soviet authors), which emerged in the run-up to the Second World War.[53] This was an offensive doctrine centred on striking deep into an enemy's rear areas following the penetration of its lines and then causing sufficient disruption to prevent an enemy from moving forces to effectively plug the hole in its lines or encircle the attacking forces.[54] Breakthrough-and-exploitation is advantageous, if achieved, in that it can overrun rear areas, and is 'designed to induce systemic collapse'.[55] If momentum cannot be sustained, offensive operations may instead aim to bite and hold objectives and ground, a less ambitious but still valid approach to operational design.[56] Of course, these concepts of operation date to the early- and mid-20th century, and the combined arms integration required for successful offensive operations of either kind will require adaptations to be made to force design, composition and structure. While many of these adaptations relate to the changing character of war and fall upon supporting arms, MBTs and the units fielding them must likewise embrace change to stay relevant.

52. Interestingly, the term 'momentum' appears to be disappearing from British doctrine. Previously it sat under the 'Manoeuvrist Approach', 'Offensive Action', and 'Seizing and Holding the Initiative' in ADP Land 2017. It was analogous to the US Army definition, which centres on tempo and retaining the initiative. However, while the overarching components remain, momentum itself only appears once in UK Defence Doctrine and not at all in the 2022 update to ADP Land. For more information, see Development, Concepts and Doctrine Centre, 'Joint Doctrine Publication 0–01: UK Defence Doctrine', 6th Edition, 2022, p. 15; Land Warfare Development Centre, 'ADP Land Operations', 2017, pp. 1A–2, 5-1–5-3; Ministry of Defence, 'ADP Land Operations: Part 2: The Application of Land Power'; Department of the Army, 'FM 3-0: Operations', pp. 2–10.
53. David M Glantz and Jonathan M House, *When Titans Clashed: How the Red Army Stopped Hitler* (Lawrence, KS: University Press of Kansas, 1995), pp. 154–56.
54. Richard Simpkin, *Deep Battle: The Brainchild of Marshal Tukhachevskii* (Washington, DC: Brassey's, 1987).
55. Biddle, *Military Power*, p. 40.
56. *Ibid.*, pp. 40–43.

III. Challenges and Necessary Adaptations

The challenges and necessary adaptations fall under several categories. Some relate to additions to the combined arms system, others to the integration of the component arms, and some to the MBTs at the core of heavy armoured forces. There are also two alternative force structures that in theory offer a warfighting capability with sufficient lethality to fight against heavy armoured forces: motorised or dismounted light forces equipped with ATGMs (but without the ability to fire them while mobile); and medium armoured forces. The utility of these alternative force structures for high-intensity warfighting is effectively a separate research question, as they are arguably in competition with heavy armoured forces. However, given that the question of their effectiveness against MBTs and heavy armoured forces overlaps with questions about the effectiveness of MBTs and heavy armoured force themselves, a brief overview is still required. More importantly, this overview encapsulates the technical challenges and adaptations required for MBTs due to the threat posed by ATGMs themselves. Armoured forces that fight on the move are mechanised, while those which fight by dismounting and working in conjunction with their infantry can be considered motorised; by this definition, for example, a Stryker brigade combat team is a motorised formation.[57] These should be addressed as two separate but related structures, against which heavy armoured forces can be subjected to comparative assessment. Another major aspect to be addressed in depth relates to the support to and sustainment of MBT-equipped formations, an understudied area which is nevertheless fundamental to their viability. Finally, there are also issues of technological change at the platform level to be considered below.

Pervasive ISTAR/Precision Strike

A combination of pervasive ISTAR, command and control (C2) modernisation and strike capabilities through precision-guided munitions have been at the forefront of the debate about the changing character of warfare and the implications for military forces. One way that this should be countered is through

57. Andrew Chack, ‘The Overmatch Dilemma: Leveraging Strengths of Stryker Cavalry Troop in Reconnaissance and Security Operations Against an Opposing Armored Force’, *Armor* (Vol. 135, No. 1, Winter 2021), pp. 21–22.

improved force protection, delivered by the adoption of new (or at least improved) capabilities and through restructuring combined arms formations. This issue has been covered extensively,[58] and while the associated debates cannot be comprehensively re-examined in this paper, suffice to say that electronic warfare (EW), artillery and counterbattery capabilities, and short-range air defence (SHORAD) all play a role. The issue is in any case largely agnostic of force type – whether light and dismounted, or medium or heavy armoured: all force types must integrate the capabilities discussed and embrace change according to the evolving character of combined arms warfare. The one caveat is that, given that heavy armoured forces have a correspondingly larger logistics footprint and greater maintenance and support requirements than most other types of forces, they may prove particularly vulnerable to this changing battlefield dynamic if combined arms integration is not effective. There are several relevant issues to cover here.

There are serious differences of opinion over the consequences of recent developments, including how to interpret the effectiveness and efficiency of C2 modernisation at moving information internally and the effectiveness of precision fires at fighting the deep battle. In the context of the difficult challenge that the deployment of uncrewed aircraft systems (UAS) imposes on land forces, the debate surrounding the best way forward often loses sight of the fact that the pervasive ISTAR and precision fires complex offers quite narrow effects. Drones and precision fires face the same inherent boundaries that aviation encountered in previous eras: aviation could attack enemy forces and systems throughout the area from the frontline to the strategic deep, and have outsized effect in certain regards, but could not independently hold ground or control populations, nor have other persistent effects. Similarly, drones and precision fires, even though they constitute a distinct line of effort, are still effectively only enablers of other ground forces. What drones and precision fires have long promised – and are now able to achieve – is attrition of key capabilities, and potentially (if targeting is done properly) the degrading of the enemy military's system of systems. Events such as Exercise *Green Dagger*, nested within the larger Exercise *Warfighter 22*, both of which took place in late October 2021, provide evidence about the potency of pervasive ISTAR, C2 modernisation and precision strike when a professional NATO force implements highly refined targeting procedures. In this instance, long-ranged precision fires cued on by a combination of UAV ISTAR and traditional forward reconnaissance patrols mauled participating

58. Weinberger, *The Imagineers of War*, pp. 68–85; Richard Simpkin, *Race To The Swift: Thoughts on Twenty-First Century Warfare* (London: Brassey's, 1985), pp. 168–69; Lester W Grau and Charles K Bartles, 'The Russian Reconnaissance Fire Complex Comes of Age', *University of Oxford Changing Character of War Centre*, 30 May 2018, <http://www.ccw.ox.ac.uk/blog/2018/5/30/the-russian-reconnaissance-fire-complex-comes-of-age>, accessed 28 September 2022; T S Allen, 'Finding the Enemy on the Data-Swept Battlefield of 2035', *Military Review* (November–December 2020), pp. 28–37.

ground forces, and while manoeuvre was possible during certain intervals, at other times ground combat formations that were identified while in unfavourable positions were heavily attrited, with few options available in response. Lighter ground forces experienced struggles of their own, with issues relating to attrition and a failure to maintain momentum in the close fight.[59] Furthermore, although the impact of new technologies was concerning, it should be remembered that open desert environments provided ideal conditions for UAS, and the lopsided performance under these conditions would not necessarily be replicable in a different climate and in more complex terrain. Even in Ukraine's Donbas region, characterised by open fields and limited cover, the extensive use of UAS – for all the changes it has wrought – has yet to prove decisive and has not pushed traditional ground combat capabilities from the battlefield.[60]

A further consideration concerns the emphasis placed on offensive capabilities without the same regard for their defensive counterparts. Following a 20-year period of counterinsurgency operations in Iraq and Afghanistan during which neither the air domain nor the electromagnetic spectrum was contested, even the exceptionally well-resourced US military has come to exhibit a mismatch between these different specialisations. While UAS and precision fires technology have been invested in and progressively refined, defensive EW, SHORAD and counter-UAS (CUAS) have received sporadic and comparatively limited attention. Of these, only CUAS has claimed a belated prominence in the discourse about the future of warfare. Forces rotating through iterations of exercises such as *Warfighter* are exploring how to address the issue, but the evidence suggests that, rather than this being an inherent offence–defence mismatch which favours new technologies, Western forces are simply playing catch-up and need to rebalance their capabilities and concepts of operations.

One resultant avenue that is often forgotten is within the broad field of camouflage, concealment, deception and decoys (C2D2), where camouflage and concealment receive far more attention than deception and decoys. Part of this is because it is easier to build standardised technical solutions or procedures to implement camouflage and concealment. Deception, on the other hand, is situation-dependent, and requires intellectual investment and problem solving for every iteration. It is also difficult to do consistently and effectively in the absence of a nuanced understanding of the adversary's procedures and mindset – understanding of enemy technical ISTAR capabilities alone will not suffice. Meanwhile, the cost of decoys can create disincentives to utilising them extensively in training,

59. Gidget Fuentes, 'U.S., International Marines Duke it Out in the California Desert', *USNI News*, 6 December 2021, <https://news.usni.org/2021/12/06/u-s-international-marines-duke-it-out-in-the-california-desert>, accessed 28 September 2022; Watling, 'Lessons from Exercise Green Dagger'; Watling, 'The Need for Speed in Confronting Peer Adversaries'.
60. Biddle, 'Back in the Trenches'.

and there is also a risk that deception and decoys will draw too much resource and undermine the main effort. Depending on the type of decoys used, significant numbers of personnel might be needed to manage them, especially if decoy units and activities are to be convincing even when viewed with a variety of different sensors and detection capabilities. (As a basic example, an enemy might be convinced that a decoy vehicle is real when viewing it in the visual light spectrum, but its thermal signature or the lack of radio frequency activity could reveal it for what it is, meaning that an enemy with capable and diligent ISTAR specialists would likely not be deceived for long.) One solution might be to homogenise the appearance and signature of ground forces, containerising logistics, ensuring that vehicles appear as similar as possible, and adopting communications systems that disguise which nodes are of critical importance – mobile ad hoc networks (MANETs) or mesh networks are a good example here, as this kind of disguise is an inherent feature of the way that they transfer data.

Likewise, simulated formation-level activity in the electromagnetic spectrum may not stand up to scrutiny if cyber analysis reveals inconsistencies or a lack of concurrent activity in the social media space, as the pervasiveness of social media and the tendency of local inhabitants to naturally document any unusual activity happening in their vicinity means that such inconsistencies can be easily detected using open sources; such activity is hard to control, suppress or convincingly fabricate. Improving the D2 element of C2D2 is therefore a challenging proposition in terms of both resourcing and overall feasibility. Nevertheless, if turned into a dedicated line of effort and practised and refined on exercise, it may prove a powerful tool for creating uncertainty, slowing enemy decision-making, and causing the misallocation of enemy resources, all of which increase the survivability of ground forces.

An alternative approach to force protection and C2D2 is that of counter-reconnaissance.[61] Although counter-reconnaissance – prioritising offensive action against an enemy's ISTAR rather than relying on passive or reactive force protection – is a longstanding concept, militaries have only partially adapted it in response to technological change. In an example that proves useful for illustrating both current challenges and potential solutions, in February 2020 the US Army's 25th Infantry Division took part in Warfighter Exercise (WFX) *20-03*, a computer-based simulation. The division found itself fighting a difficult initial shaping battle against enemy long-ranged precision fires and ISTAR assets due to attrition that these enemy capabilities were causing. Passive and reactive air defence deployed against UAS proved inadequate, and so the division approached the problem not as one of force protection but of prioritising the

61. Department of the Army, 'FM 3–98: Reconnaissance and Security Operations', 2023, pp. 5-4–5-5.

targeting and destruction of enemy ISTAR in order to break their kill chain.[62] The 25th Infantry Division attempted to target different elements throughout the kill chain – the UAS themselves, dismounted forward observers, and UAS ground control stations, as the launchers for enemy indirect fires were assigned to corps-level assets.[63] They had little success against UAS, downing some systems but being unable to destroy enough to have any overall effect. UAS ground control stations were identified as a more vulnerable element of the kill chain. The prioritisation of the counter-UAS battle, and the detection and collation of the enemy forces' electronic and signals signature allowed the division to understand what effects they needed to apply and where, though the division's own C2 processes proved insufficiently integrated to consistently destroy identified targets or render the enemy's UAS network ineffective until the division could adapt and reorganise these processes. While this adaptation was taking place, the division's ground manoeuvre elements had been badly attrited.[64]

While accepting the limitations of such simulations in terms of realism, even those as well-resourced and layered as *Warfighter*, and that the measures taken achieved only partial success within the duration of the exercise, nonetheless the division's identification of the least successful line of effort (kinetic CUAS) and the most promising (aggressive counter-reconnaissance against enemy ground stations) provides a useful indicator of the direction that force restructuring and the reform of concepts of operation should take. Overall, for heavy armour to be survivable, combined arms formations need to be able, one way or another, to prevent an enemy from saturating the battlespace with UAS, disrupt or slow down the links between UAS sensors and the precision weapons to which they feed targeting information, and to retain the ability to deceive.

Alternative Ground Combat Force Structures

ATGMs and Fighting Dismounted

In the direct fight, increasingly capable ATGMs pose the most obvious threat to MBTs. While opposing MBTs can be armed with barrel-launched or tube-launched ATGMs, the fact that ATGMs do not rely on velocity means that they can be launched from a tube, and that in theory any light vehicle or dismounted soldier

62. Benjamin Scott, 'Army Counter-UAS 2021–2028', *Military Review* (Vol. 101, No. 2, March–April 2021), pp. 67, 69.
63. *Ibid.*, p. 67.
64. *Ibid.*, pp. 65–69.

can thus be equipped with an effective anti-tank weapon.[65] The technology continues to develop, and at present the lethality of modern systems such as Javelin, NLAW and Kornet is difficult for MBTs to counter directly. The most effective ATGMs, such as Javelin, have a top-attack function whereby the missile guides itself via an irregular trajectory to strike the weaker top armour of a targeted vehicle. Top-attack munitions also have the advantage of being difficult to counter with active protection systems (APS), as these must track and calculate the trajectory of the incoming missile in order to intercept it. However, ATGMs come at a high per unit cost, and top-attack munitions are the most expensive of all (and will require skilled operators until sensor and guidance technology improves). They are also bulky and heavy for dismounted infantry to carry, not to mention the difficulties of a dismounted unit carrying more than a handful of spare missiles with it, are slow to reload compared with the main gun of an MBT, and so have severe tactical constraints, even if they are more lethal in absolute terms. In a direct line-of-sight fight with MBTs and heavy armoured forces, the operators of ATGMs can be vulnerable, although if they are well-sited and implement good battlefield discipline to minimise their visual signature, they are very difficult to spot and can be used to conduct effective ambushes.

ATGM use by lighter armoured forces bears consideration, as these forces can in theory conduct offensive operations. Here, it is worth differentiating between mounted and dismounted forces. The US experience is that any medium formation that requires dismounts for lethality will be difficult to manage because of the constant transition between mounted and dismounted tactics.[66] The British experience of exercising dismounted ATGM-armed light cavalry forces in the anti-armour role resulted in similar conclusions. Such forces are versatile and effective in defensive operations but difficult to use for offensive purposes due to the time required to manoeuvre and deploy them.[67] In order to attack a heavy armoured force, a medium armoured force without mobile anti-armour capabilities of sufficient lethality will generally need to move to within 3 km of the enemy, advance or infiltrate on foot, and engage with man-portable anti-armour weapons. If the medium motorised force is paired with more mobile anti-armour capabilities such as heavy armour of its own, these dismounts can operate in a targeting role,[68] but this points to their being a complementary capability rather than a substitute.

There are some advantages to motorised anti-armour capabilities. On operations in Afghanistan, without tracks and with a quiet engine, Strykers were found to

65. House, *Combined Arms Warfare in the Twentieth Century*, p. 143.
66. Chack, 'The Overmatch Dilemma', pp. 22–23.
67. British Army, 'Tactical Employment Note: Armoured Cavalry in the Armoured Brigade Combat Team', internal unpublished document.
68. Chack, 'The Overmatch Dilemma', p. 24.

be able to approach targets without being detected before deploying their dismounts.[69] However, displacement and exfiltration is difficult in general, as is manoeuvre. If a medium motorised force is committed against a heavy armoured force, the sub-units that make contact with the enemy will lose momentum and the initiative, although they will be able to hold ground and retain lethal effectiveness.

In complex terrain, medium motorised forces may fit operational needs. During the Battle of Irpin in the Russo-Ukrainian War, Ukrainian infantry forces armed with ATGMs were not only lethal but also extremely mobile. However, the terrain around Irpin, Bucha and Hostomel is not conducive to armoured and mechanised mobility: the three suburbs are bounded by dense forest, and most of the open ground is part of the marshy floodplain around the Irpin and Bucha rivers, presenting a further obstacle.[70] The village of Demydiv was one of many deliberately flooded to block Russian movement.[71] The Russian Army did use light infantry in its attempts to manoeuvre away from the main roads, but these performed poorly. However, the battle was one of urban and forest fighting that heavily favoured the defender, and Ukrainian victory owed much to Russian planning failures – both factors being situational and not necessarily replicable.

Furthermore, evidence from Ukraine suggests that fighting armoured forces is difficult and dangerous for ATGM-armed dismounted light infantry, even if they possess Javelin, one of the most effective and lethal systems currently available. If such forces are detected by enemy tank crews they become acutely vulnerable to the tank's main armaments, which cause large numbers of casualties.[72] The main gun of an MBT can also outrange all but the most capable of ATGMs, such as Javelin, and the evidence from Ukraine indicates that the addition of thermal shielding to Russian T90s could successfully reduce the effective range of Javelin to well within that of the vehicle's main armament by making it harder for the command launch unit to lock on to targets.[73]

69. Kevin Hymel, 'Strykers in Afghanistan: 1st Battalion, 17th Infantry Regiment in Kandahar Province 2009', Combat Studies Institute Press, 2014, pp. 4, 83.
70. Author observations of the battlefield terrain during fieldwork in Ukraine, June 2022.
71. Andrew E Kramer, 'They Flooded Their Own Village, and Kept the Russians at Bay', *New York Times*, 27 April 2022.
72. Interview with Canadian volunteer to the Ukrainian Army, 'Canadian Fighting in Ukraine Describes the "Hell" he Witnessed', *CBC News: The National*, 5 May 2022, <https://www.youtube.com/watch?v=zN2NdiFJFh0>, accessed 20 September 2022; Scott Peterson, 'Russian War's "Phase 2": How Ukraine Troops Adapt, Giving Little Ground', *Christian Science Monitor*, 4 May 2022, <https://www.csmonitor.com/World/Europe/2022/0504/Russian-war-s-Phase-2-How-Ukraine-troops-adapt-giving-little-ground>, accessed 17 May 2022; Michael Schwirtz and Lynsey Addario, 'In the Trenches of Eastern Ukraine, Combat Becomes a Vicious Dance', *New York Times*, 11 May 2022; battles.and.beers, interview with Ukrainian soldier, Instagram post, <https://www.instagram.com/p/CerMWnLuwCm/>, accessed 25 October 2022.
73. Author interview with Deputy Commander of Northern Command, Ukraine, April 2023; author interview with a Battalion Commander and Deputy Battalion Commander in 1st Tank Brigade, Ukraine, April 2023.

Ultimately, the presence of ATGMs on the battlefield puts pressure on armoured forces, and is driving changes to tank design (such as the adoption of APS), prompting weight increases – as will be discussed later. Conversely, the presence of armour requires the careful husbanding of anti-tank capabilities which would otherwise be useful for other tasks. For example, the British Milan ATGMs deployed in the Falklands War, which were used in an anti-fortification role and were critical to overcoming dug-in Argentine infantry and marines,[74] would have been less available (if available at all) for those tasks had the British task force been simultaneously guarding against the threat of even a small Argentine armoured force. ATGMs pose a distinct threat, but cannot lay claim to having made the MBT obsolete.

Medium Armoured Forces

Medium tracked armoured forces require the briefest commentary, as they are most similar to the heavy armoured forces built around MBTs. They operate on the same principles, but are comparatively lighter, less protected and carry less firepower, and they have the same drawbacks (albeit to a lesser extent in some regards). RAND conducted a study of the utility of medium tracked armoured forces, and concluded that they performed well, and benefited significantly from strategic, operational and tactical mobility and a less burdensome logistics requirement, but also found that their reduced combat power resulted in less successful outcomes if they were deployed against competent heavy armoured forces. These outcomes could only be offset by either close air support and artillery dominance or by the opposing heavy armoured forces not being employed competently (and without combined arms integration of their own).[75] This study factored in the use of ATGMs (both vehicle-mounted and carried by dismounts) by medium armoured forces.[76] The history of US light and medium armoured forces in the Second World War, at the point when they encountered German heavy armoured forces with a significant combat power advantage in the direct fight, was not a happy one, and involved significant losses, an experience that still shapes current US thinking on the employment of MBTs. This has been termed the Sherman Dilemma,[77] whereby a force adopts a less-capable combat vehicle with the expectation that combined arms integration will offset its

74. Martin Middlebrook, *Operation Corporate: The Falklands War, 1982* (New York, NY: Viking, 1985), pp. 268, 338–39, 344–46, 369–71; Max Hastings and Simon Jenkins, *Battle for the Falklands* (London: Pan Macmillan, 2010), pp. 246, 279, 310, 374, 382.
75. Johnson, Grissom and Oliker, *In the Middle of the Fight*, pp. xvi–xvii, 147–56.
76. *Ibid.*, pp. 56–58, 62, 70, 76–77, 92–95, 122–27, 206–21.
77. *Ibid.*, p. 153.

disadvantages in the direct fight, only to discover that combined arms integration does not provide the expected benefits under actual operational conditions.[78]

The category of medium forces is quite a varied one. The US Army Stryker formations fit at the lower end of the category, at just over 16 tonnes; although the MGS variant was armed with 105-mm main gun, this made for a top-heavy and unstable vehicle (mechanical issues with the turret were also an issue), and this variant was eventually retired.[79] Thus, Stryker formations remain reliant on ATGMs for lethality when engaging heavier forces. Meanwhile the British Army's Ajax vehicles, which weigh 38 tonnes, occupy the upper end of the medium forces category. The dividing line between 'medium' and 'heavy' forces, in fact, is blurred, as many MBTs – particularly those of Soviet or Russian design – are considerably smaller and lighter than their Western equivalents: for example, the T90 weighs 48 tonnes,[80] while the T72 weighs only 46 tonnes.[81] An alternative framing might be that, given the obvious pressures on heavy armoured forces, that heavy armoured vehicles and MBTs, when they are employed, should perhaps be lighter in future. However, as will be discussed in the section on logistics, sustainment, recovery and reconstitution, adopting Soviet design principles to achieve this end would be unwise.

In addition to their lesser logistical/sustainment requirements and increased deployability, medium armoured vehicles enjoy niche advantages over their heavy counterparts. Medium armoured vehicles with rapid-firing main armaments can generally hyper-elevate their guns compared with standard MBT designs, and therefore have a tactical advantage in urban, mountainous or complex terrain (noting the exception of the South Korean K2 Black Panther MBT, whose innovative suspension system allows the engagement of high- and low-angle targets).[82,] However, when it comes to warfighting, the evidence suggests that medium armoured forces have consistently been at a disadvantage against heavy armoured forces, resulting in high losses when these two force types go head to head in the direct fight. Overall, these different force structure options are best seen as being complementary, rather than as substitutes for each other.

78. Author interview with retired US Army General Officer, Washington, DC, October 2022; Johnson, Grissom and Oliker, *In the Middle of the Fight*, pp. 153–55.
79. Stephen Losey, 'The Army is Ditching All of its Stryker Mobile Gun Systems', *Military*, 12 May 2021, <https://www.military.com/daily-news/2021/05/12/army-ditching-all-of-its-stryker-mobile-gun-systems.html>, accessed 20 November 2022.
80. *Catalog Rosoboronexport*, 'Main Battle Tank (MBT) T–90MS', <http://roe.ru/eng/catalog/land-forces/tanks/t-90ms/>, accessed 11 August 2022.
81. *Catalog Rosoboronexport*, 'Main Battle Tank (MBT) T–72M1', <http://roe.ru/eng/catalog/land-forces/tanks/t-72m1/>, accessed 11 August 2022.
82. Caleb Larson, 'South Korea's K2 Black Panther Tank Has One Mission', *National Interest*, 23 December 2020, <https://nationalinterest.org/blog/buzz/south-korea%E2%80%99s-k2-black-panther-tank-has-one-mission-175048>, accessed 18 November 2021; Johnson, Grissom and Oliker, *In the Middle of the Fight*, pp. xvi–xvii, 147–56.

Wheels and Tracks

Wheels and tracks remain a recurring topic of discussion, and therefore should be briefly acknowledged. The discussion continues even though the dynamics, in themselves, are generally agreed. It has already been mentioned that more difficult terrain will generally be more easily traversed by tracked vehicles, whereas wheeled vehicles will have to move more carefully and be more selective about their route – or indeed may not be able to cross the same terrain at all if it is sufficiently difficult. The implication is that the choice of routes, tactical formations, and use of ground for cover involving both tracked and wheeled vehicles will force the formation to conform to the mobility capacity of the least capable vehicles. Alternatively, concepts of operation need to make allowances for a disjoint between the wheeled and tracked elements of the force, and accept them not operating entirely in tandem. Incidentally, different types of vehicle may also experience interoperability issues, even if they fit within the same category. For example, CVR(T), though extremely useful in Afghanistan and other theatres,[83] suffered in the First Gulf War in large part because, on the advance in open terrain, it could not keep pace with the Challenger- and Warrior-equipped heavy armoured forces for which it was supposed to provide forward reconnaissance.[84]

Despite these challenges, wheels and tracks have often been forced to operate together out of necessity, as even the best-resourced militaries must go to war with the equipment they have available – and this sometimes involves integrating disparate platforms and units. Wheels and tracks can verifiably work together successfully. However, where it is economically feasible, states with heavy armoured forces have tried to maintain as much commonality or similarity of hull and drivetrain as possible within formations. This should remain an aspiration, if British Army vehicle fleets can be rationalised over time.

Logistics, Sustainment, Recovery and Reconstitution

Micah Clark has argued that: 'An experienced tank crew is the ultimate combat power multiplier for its ability to conduct field-expedient maintenance to

83. Reynolds, 'Learning Tactical and Operational Combat Lessons for High-End Warfighting from Counterinsurgency', pp. 46–47, 51.
84. Matt Baker, 'Operation Desert Sabre: 1st British Armoured Division', British Army Review Special Report – The Gulf War, Vol. 1, Winter 2020, pp. 26–27.

unconventionally repair issues that would otherwise render a tank non-mission capable'.[85]

Given the threat environment, MBTs need to remain mobile to avoid detection and targeting – but this creates dilemmas when factoring in the need to go static in order to conduct maintenance and repairs. Thorough preventative maintenance in garrison is a first step,[86] but even with new vehicles, in good order, armoured forces require constant maintenance to keep them operational, and consume significant volumes of supplies. A squadron of MBTs requires a large amount of fuel, and heightened mobility will proportionally heighten the logistics burden for fuel resupply. Likewise, crews require rest, which the increased maintenance burden inherent in MBTs disrupts, further degrading operational tempo compared with simpler wheeled platforms.

In addition to the key characteristics of protection, mobility and firepower that ground combat vehicles embody, Yoo, Park and Choi identified operability as the fourth key function.[87] While the standing of operability as an equal consideration is open to debate, it is nonetheless important to highlight overall logistics and sustainment functions. Clark's observation referenced above is often underappreciated, except by armoured personnel themselves, and 'the often-overlooked operator's perspective calls for the focus to fall on maintainability in the field over incremental upgrades to firepower and survivability'.[88] Future MBTs and heavy armoured vehicles should be designed and constructed with modularity and repairability in mind, ensuring that as many repairs as possible can be completed on-site by the vehicle crews themselves, without having to recover the vehicle to a rear maintenance area or bring forward specialist repair crews; this dynamic is a much-overlooked – but critical – element in influencing heavy armour's effectiveness.[89]

Likewise, recovery of immobilised MBTs is challenging, especially under fire, requiring well-practised and properly-equipped recovery crews if it is to be effective, but it can allow technically killed vehicles to be rapidly returned to service if they can be withdrawn from enemy contact and evacuated to forward repair facilities.[90] Delays to recovery operations in Afghanistan for damaged Stryker vehicles could fix units for 24 hours even when recovery vehicles were readily available. Units were forced to defend what proved a tempting target for

85. Micah Clark, 'What Do Future Main Battle Tanks Need to Succeed? Ask the Operators', *RUSI Defence Systems*, 25 March 2019.
86. Colin P Mahle and Charles L Montgomery, 'There is No Conflict Between Maintenance and Training: How to Establish an Effective Unit Maintenance Culture', *Armor* (Vol. 138, No. 4, Fall 2021), pp. 53–57.
87. Yoo, Park and Choi, 'The Vulnerability Assessment of Ground Combat Vehicles Using Target Functional Modeling and FTA', pp. 651–58.
88. *Ibid.*
89. *Ibid.*
90. *Ibid.*, pp. 84–89.

insurgent attacks,[91] showing that the challenges of recovering and repairing heavier vehicles in warfighting conditions should not be underestimated.

The Second World War, although in many regards a dated case study, provides some critical lessons. In particular, the long duration of the war means that the multiple campaign seasons, large distances covered by advancing and retreating units, and the intensity of fighting (which resulted in high levels of tank loss) can provide useful insights into questions around the extended sustainment of heavy armoured forces in the face of attrition during warfighting campaigns,[92] even if some fundamental differences can be identified with regard to contemporary scenarios (discussed below).

The Soviet experience on the Eastern Front in the Second World War was that tanks might be knocked out, repaired and returned to service as many as four times during an operation.[93] Tanks lost in a repairable state outnumbered those which were irrecoverable by two-to-one.[94]

Wartime and post-war Soviet research found that on average during an operation which lasted 15 to 20 days the overall tank loss rate was 82% of the starting strength, with 70% of the losses being repairable and 30% of the repairable losses due to non-battle reasons such a mechanical problems or getting stuck in a swamp.[95]

After approximately 20 days of constant operation, the Soviet Army found that the breakdown rate started to escalate dramatically, illustrating the importance of preventative maintenance.[96] If Soviet forces lost ground, the rate of irrecoverable tank losses would increase dramatically as repairable tanks – and, in the worst-case scenario, tank repair facilities and recovered tanks undergoing repairs – were overrun and fell into German hands.[97] Recovery and maintenance personnel organic to tank formations were invaluable: not only were they well-placed to quickly conduct repairs, but – if well-led – were likely to consider themselves an integral part of the team and perform better than centralised recovery and maintenance personnel based at higher or rear echelons; moreover, additional benefits were derived from their familiarity with specific vehicles.[98] The importance of stocks of spare parts should not be underestimated, an oversight

91. Hymel, 'Strykers in Afghanistan', pp. 84–85.
92. Burkhart H Mueller-Hillebrand, *German Tank Maintenance in World War II: An Historical Study* (Washington, DC: Center of Military History, 1982), p. 41.
93. Gary A Dickson, 'Tank Repair and the Red Army in World War II', *The Journal of Slavic Military Studies* (Vol. 25, No. 3, 2012), p. 385.
94. *Ibid.*
95. *Ibid.*, p. 389.
96. *Ibid.*, p. 385.
97. *Ibid.*, p. 391.
98. Mueller-Hillebrand, *German Tank Maintenance in World War II*, pp. 42–43.

which plagued German forces in the Second World War, as a lack of spares could turn what should have been a quick repair job into a lengthier delay as tanks spent an extended period of time in the care of a maintenance unit, awaiting the necessary parts.[99] Another flaw in the German operation was that cannibalisation of vehicles and inter-unit competition exacerbated the system's deficiencies and meant that more damaged or broken-down tanks were unavailable than otherwise might have been the case.[100] Interestingly, the experience of German tank crews was that, although they were trained to conduct basic repairs and could in theory assist the dedicated mechanics, in practice (when accompanying badly damaged tanks to rear echelon maintenance facilities) some crews had a tendency to interfere with the work of the maintenance personnel and generally make a hinderance of themselves unless other activities could be found to keep them occupied.[101] Although this dynamic is at odds with the experience of well-trained modern crews,[102] it is worth bearing in mind for unit commanders.

Gary Dickson's distillation of the Soviet experience bears citing in full:

> The number of tanks in service at any one time during a battle was very dynamic. On the minus side tanks were being destroyed or damaged due to battle or non-battle reasons. On the plus side was only the ability of the repair units to put damaged tanks back into service. Therefore the pool of damaged tanks was a great asset to a tank unit as long as they could be repaired in a timely manner. This had several significant consequences:
>
> 1. As long as repair units were able to repair all or most of the tanks which were damaged, a tank unit was able to maintain its strength, only slowly weakening due to irrecoverable losses and the time it took to repair tanks.
>
> 2. The faster a tank unit advanced, the farther behind the repair units lagged and the more time they had to spend moving to keep up. Both reduced the number of tanks which could be repaired.
>
> 3. Retreat was a potential disaster for the damaged tank pool. With a limited number of evacuation vehicles, most tanks had to be abandoned on the field, never to be repaired. Loss of the damaged tank pool resulted in a dramatic reduction in tank strength.

99. *Ibid.*, pp. 43–44.
100. *Ibid.*, pp. 21–26.
101. *Ibid.*, p. 20.
102. Clark, 'What Do Future Main Battle Tanks Need to Succeed? Ask the Operators'.

> 4. Operational pauses were critical and allowed repair units time to catch up and clear the backlog of tanks to be repaired. This, and the fact that it did not retreat and lose its damaged tank pool, is why the 5th Guards Tank Army was able to reconstitute itself after the battle at Prokhorovka.[103]

Most of these points remain entirely valid for the modern employment of heavy armour.

More recent experience complements these lessons. The South African Defence Force (SADF) in the Border War provides an interesting example of an armoured force operating at reach and lacking mass, which could neither rotate formations nor reconstitute them during operations. In Operation *Hooper*, as the majority of the SADF's armoured strength had been assembled, SADF Ratel IFVs and Olifant MBTs could not be replaced and had to either forgo maintenance – sometimes for up to 800 hours of combat – or be refitted at the front by their sub-unit mechanics. Both wear and tear and combat damage aggregated, whittling away at the number of available vehicles, and those that did go into combat often did so in a degraded and less effective state. This contributed to the inability of the SADF to maintain operational momentum and reinforce or exploit successful offensives.[104] Concurrently, Cuban airpower served to limit SADF frontline resupply and maintenance. In most regards frontline combat units were kept supplied, albeit austerely, or could make do without non-critical items. However, spare parts for artillery and armoured vehicles were the two areas in which the logistics problems could not be solved through improvisation, resulting in ever-reducing capability due to the importance of armoured and indirect fire support and the heavy maintenance burden imposed on the units in question by the high and sustained operational tempo.[105]

In terms of lessons learned from recent operations in Ukraine, the majority of Russian armour losses have still been the result of poor maintenance or logistics.[106] In the case of the Ukrainian armed forces, the majority of repairs are carried out up to 300 km away from the frontlines in order to protect irreplaceable maintenance machinery and personnel from artillery fires. While the journey from the frontline to these facilities could be only five or six hours,[107] an impressive feat of logistics in itself, this still constitutes a major endeavour. In the summer

103. Dickson, 'Tank Repair and the Red Army in World War II', pp. 391–92.
104. Leopold Scholtz, *The South African Defence Forces in the Border War 1966-1989* (Solihull: Helion, 2015), p. 346.
105. *Ibid.*, pp. 410–13.
106. Interview with Colonel Mykola Salamakh, 'Танки у російсько-українській війні. Микола Саламаха' ['Tanks in the Russian-Ukrainian War. Mykola Salamakh'], *Мілітарний*, <https://www.youtube.com/watch?v=ktJNrw6dxwo>, accessed 28 September 2022.
107. *Ibid.*

of 2022, Ukrainian tanks that had been destroyed on the battlefield, but recovered, were being repaired in Poland at a rate of 20–30 per month.[108]

This all has implications for the current and future operational contexts for Western forces: unless formations can be furnished with ample layered air defences or the enemy thoroughly blinded by counter-reconnaissance operations, the requirement to keep major maintenance hubs safe from as much of the enemy's precision fires as possible will probably necessitate them being based far from the frontlines. This could make tank pools less vulnerable to overrun, but would also mean that the tank pool would not be able to reconstitute armoured units as responsively as might be desired given the greater geographical distance between them and the units deployed forward. This would also increase coordination challenges and reduce the benefits of repair units being associated with frontline formations (the echelon at which maintenance units should be held). As well as creating the traditional logistics problems, this would also entail the concentration of large numbers of vehicles under repair, creating a large signature that could be detected and targeted even if located deep in the rear. Forward repair units should therefore be structured, equipped and protected in such a way as to operate dispersed and avoid developing a backlog of tanks under repair, while investment in education, training and track miles in developing crew skills will be key determinants of their ability to keep vehicles operable, enabling many repairs to be completed without the assistance of mechanics or the need for a vehicle to be recovered.[109]

In terms of the scale at which forces operate, policymakers and senior leaders should understand that in order to credibly generate a warfighting capability at a given scale – be it battle group, brigade or division – a military will require sufficient depth to rotate it with a counterpart formation. Furthermore, avoiding spending on spare parts will amount to a false economy, and one that has in previous conflicts proved disastrous on operations. A sustainable supply of a large number of spare parts should be factored into procurement and fleet management decisions, otherwise a force may be exposed to excess attrition during warfighting and will accumulate an unnecessarily high level of permanently lost vehicles.

Changes to Tank Design

There are a number of changes to tank design that can be suggested, implemented either through modifications to existing vehicles or by including them in more

108. *Ibid*.
109. Author interview with a British Army armoured officer and field introduction to Challenger 2 MBT, Tidworth, July 2021.

comprehensive upgrade programmes. Unfortunately, some of these will prove impossible to implement even within the framework of the ongoing Challenger 3 upgrade, but these could still be made at a later date.

MBTs and heavy armoured forces require better ISTAR capabilities, both within and beyond line-of-sight. Beyond line-of-sight, one capability that should be integrated into heavy armoured forces is UAS reconnaissance to assist with tactical-level detection (although this point is force type-agnostic – light and medium forces equally require this capability). Within direct line-of-sight, ‘see-through armour’ (a type of augmented reality) is promising, although literally transparent armour[110] is far enough away from being practicable to be discounted for the moment). See-through armour involves mounting high-resolution cameras on the outside of the vehicle and using software to merge their feeds together to give the crew an expanded view that eliminates blind spots, allowing them to look in different directions more quickly than is possible with traditional sights and viewports.[111] Given that kinetic strikes against the vehicle’s armour will quickly damage or destroy cameras, the existing series of armoured viewports and optics should not be eliminated, but see-through armour capability would still reduce the chances of MBTs being successfully ambushed or blundering into ATGM-armed dismounts without warning (both scenarios that can reduce the advantages normally held by heavy armoured forces).

Refining MBTs’ onboard optics and detection systems is another important avenue of improvement. Challenger 2 remains an impressive sensor platform, with both electro-optical and thermal optics able to identify targets beyond the effective range of direct fire anti-tank weapon systems if the crew actively scans the right arcs and areas. However, upgrading the range and fidelity of sensors and, more importantly, increasing their field of view is an obvious area for ongoing improvement, and one that private industry will continue to provide new commercial-off-the-shelf options for due to the wide applications.

Detection systems operating outside of the visual light spectrum should also be considered, such as laser and radar warning receivers: it is already planned that

110. Kevin A Masser et al., ‘Transparent, Methacrylate-based Polymer Networks with Controlled Crosslinker Ductility’, *Journal of Applied Polymer Sciences* (Vol. 138, No. 3, 2021).
111. Joseph Trevithick, ‘Israel Unveils Updated Armored Command Vehicle and Will Give Merkava Tank Crews X-Ray Vision’, *The Warzone*, 29 August 2018, <https://www.thedrive.com/the-war-zone/23249/israel-unveils-updated-armored-command-vehicle-and-will-give-merkava-tank-crews-x-ray-vision>, accessed 20 June 2023; Samuel Cranny-Evans, ‘IronVision Trialled on Challenger 2 Streetfighter II’, *Janes*, 16 January 2020, <https://www.janes.com/defence-news/news-detail/ironvision-trialled-on-challenger-2-streetfighter-ii>, accessed 31 October 2023; Hensoldt, ‘SETAS – See Through Armour System’, <https://www.hensoldt.net/products/optronics/setas-see-through-armour-system-for-armoured-vehicles/>, accessed 20 June 2023; BAE Systems, ‘Battleview 360’, <https://www.baesystems.com/en-uk/feature/cutting-edge-technology-so-soldiers-can-see-through-vehicles>, accessed 20 June 2023.

Challenger 3 will be equipped with a laser warning receiver.[112] As this type of system can only feed data to APS or provide immediate warning of an enemy contact, other forms of sensor may also prove useful in increasing situational awareness. Retro-reflective detectors, ground-moving target indicator (GMTI) radar and synthetic aperture radar (SAR)[113] are all options that would provide advance warning of surveillance – although these come with constraints: passive retro-reflective detection seems unlikely to be able to distinguish scopes and sensors from coincidental backscatter and reflections from other sources, particularly in urban environments, and so an active laser emitter would probably be necessary bar any unexpected technological breakthrough. GMTI and SAR systems, meanwhile, would be best mounted on an antenna and thus might only be deployable when static; these systems would therefore not give passive protection at all times, but would provide the capability to periodically scan for threats, and would require a tactical pause or short halt to do so. Note the risk of the radar emissions being detected must be factored in when considering such options.

This in turn raises questions about crew and commander workload and about the echelon level at which these systems could be integrated. While a retro-reflective detection scan produces near-instant results, outside of a headquarters setting GMTI data would require artificial intelligence (AI) support to even partially automate target classification – and even then the data would still require human analysis to filter out clutter and noise. These systems may therefore be inappropriate for platform-level integration. The commander of an unmodernised Challenger 2 already has a high cognitive burden when managing a tank crew and, in the case of sub-unit commanders, also has a troop or squadron to oversee. Maintaining situational awareness while closed down takes practice, given the limited fields of view and the fact that rotation of the turret where the commander is located is independent of the position and direction of travel of the hull – even before the designation of targets, issuing of other instructions, and communicating via radio inter- and intra-echelon are taken into consideration. In addition, space is at a premium in the turret given the battle management systems already in place.[114] This situation is unlikely to change with the introduction of Challenger 3.

When considering the adoption of extra systems, one caveat is that there is limited space available in the current Challenger 2 turret for additional battle

112. *RBSL*, 'Challenger 3 vs Challenger 2', <https://rbsl.com/assets/news-images/RBSL-infographic---Challenger-2-vs-Challenger-3-(1)-1620408197.pdf>, accessed 7 October 2022.

113. X-band, Ka-band and Ku-band, or between 8–40Ghz, are theoretical options for this type of radar detection.

114. Author interview with a British Army armoured officer and field introduction to Challenger 2 MBT, Tidworth, July 2021.

management and situational awareness equipment.[115] In order to prevent intended improvements being counterproductive for the crew operating the platform, it would be much more preferable to undertake a wholesale overhaul of the interior ergonomics and a thorough integration of new capabilities with existing ones, rather than incrementally add systems in a piecemeal manner. It would be a mistake to add systems that require a significant level of management by tank commanders; such systems should instead be operated either by attached specialists or handled an echelon above, with data passed down, using AI support to ensure that the cognitive effect on the tank commander is beneficial rather than overwhelming. There are also serious questions about whether these technologies could be added to MBTs without increasing their weight to an impractical level.

With regard to the proposition that future MBTs and heavy armoured vehicles should be lighter, John Stone argued this exact point when he noted that, although the US and the UK adopted manoeuvre warfare as the core of their warfighting doctrine in the 1980s, their MBT designs were still rooted in the 1970s in terms of size, amount of armour, and weight (60–70 tonnes). In Stone's view, the logistics tail made necessary by this misalignment of concepts of operations and vehicle design amounted to a bloating that directly impeded the very operational tempo and mobility that the vehicles were supposed to enable.[116] Whether Stone was correct or not, MBTs certainly cannot afford to get any heavier than they are now. Once a tank weighs above approximately 80 tonnes, the engineering and design choices required to overcome increasing ground pressure result in vehicles that are useful only for niche tasks or which are simply impractical.[117] Even at 70 tonnes, problems abound. The Department of Defense (DoD) and US Army have in the past been at odds over whether tests indicated that weight increases had compromised the Abrams M1A2 SEPv3 MBT's ability to cross standard bridging equipment, be carried by Heavy Equipment Transporter System (HETS), and be recovered in the event of damage or breakdown.[118] Nor does Challenger 2 enjoy the same cross-country mobility as its smaller forerunner, the Centurion.[119] The current balance between weight and equipment requirements may be the best balance possible given the threat environment, but seeking further protection may prove counterproductive and mobility issues should not be exacerbated, as mobility too is critical to survivability, allowing tank crews to better use ground and avoid slow movement or being forced into remaining static.

115. *Ibid*.
116. Stone, *The Tank Debate*, pp. 11–12.
117. Kenneth W Estes, *Super-heavy Tanks of World War II* (Oxford: Osprey, 2014), pp. 9–46.
118. Jen Judson, 'Creeping Weight of Abrams Tank Concerns Pentagon's Chief Weapons Tester', *Defense News*, 26 January 2021.
119. Salmon, *To the Last Round*, p. 100.

Despite the potential benefits of moving to lighter vehicles, Russian design principles for MBTs, which might be characterised as being design-optimised for ease of manufacture and extreme mechanical simplicity, are probably best avoided. As Michael Kofman recently highlighted, Western platforms, particularly armoured vehicles, have proven significantly more survivable than Russian-designed and -manufactured equivalents. Despite a similar vulnerability to being mission-killed, crews are far more likely to survive and vehicles are more likely to be recoverable and repairable.[120] This results in forces that can be organically reconstituted far more easily.

Ultimately, increased battlefield lethality might make it difficult to achieve improved survivability through passive or reactive protection. Technological developments in this area might offer some promise, but also involve limitations. For example, expectations of the benefits to be derived from countermeasures such as APS should be moderated. APS have a high power demand when they are active, and some vehicles cannot provide such power.[121] Moreover APS, when active, also involve the use of radar guidance, generating an associated electromagnetic signature that in theory could assist enemy targeting. APS are also generally single-use or quickly expended, such that a moderate volume of incoming fire can overwhelm even an effective and reliable APS, leaving the vehicle in question reliant on its passive protection systems. APS technology may provide a layer of protection, but is no guarantee of survivability against a determined or well-armed enemy. They are most effective when heavy armoured forces can concentrate and quickly overwhelm an enemy, whether that enemy is equipped with heavy armour itself or is composed of lighter forces armed with anti-tank weapons. Improved ISTAR capabilities and situational awareness technologies, coupled with concepts of operations that prioritise counter-reconnaissance, may be the best way to ensure that the MBT remains a viable platform.

Uncrewed Ground Vehicles (UGVs)

A final question is whether the role of the MBT can be performed by UGVs. Unfortunately for enthusiastic technologists, the answer is that the future MBT will not be able to operate uncrewed any time soon. A hypothetical head-to-head comparison with the MBT will serve to illustrate the shortcomings of UGVs. UGVs can be controlled remotely, or they can be autonomous. If they are controlled

120. Michael Kofman, 'Lessons from Ukraine', speech at the RUSI Land Warfare Conference, London, 26 June 2023.
121. Joseph Trevithick, 'Thousands of Army Bradleys Don't Have the Power to Use New Active Protection Systems', *The Drive*, 3 February 2020, <https://www.thedrive.com/the-war-zone/32068/thousands-of-army-bradleys-dont-have-the-power-to-use-new-active-protection-systems>, accessed 27 September 2022.

remotely, they rely on data links, which present a vector for attack – they can be hacked, or the signal can be disrupted. Alternatively, UGVs can be autonomous, but this presents its own problems – most importantly, the technology controlling the UGV's autonomous performance must be mature and sophisticated enough for the vehicle to be useful. UGVs of both kinds will perform best if managed by human personnel nearby, and these personnel must be protected.

Crewed MBTs do not suffer from any of these disadvantages. An armoured vehicle such as a modern MBT is extremely versatile: it can be employed with a great deal of precision, can operate independently for an extended period of time fulfilling a variety of different mission-sets, and can rapidly switch between these mission-sets, provided it has a well-trained and competent crew. For example, on a single patrol, an MBT crew could, if required, perform a variety of different combat missions with tactical flexibility, including patrolling, reconnaissance, attacking, and holding or defending ground. The crew can handle surrendered enemy combatants, provide limited on-the-spot humanitarian relief such as first aid or emergency supplies to civilians, and conduct maintenance on its vehicle, and do all of this independently in extremis. While an MBT and its crew are not optimised for many of these tasks, and might perform some of them poorly if unsupported or in an environment not conducive to them completing that task effectively, they could nevertheless turn their hand to different tasks as necessity dictated. This range of capabilities is a difficult standard for a UGV to match.

There are, however, situations where the UGV concept can complement the use of MBTs. For instance, in tanks where the crew operates the turret remotely from inside the hull (Remote Weapons Stations, RWS) some elements of UGV technology could be leveraged, making the vehicle less vulnerable to enemy fire when taking hull-down positions. Crewed vehicles also provide useful platforms for mounting the infrastructure required to supervise UGVs and for stationing their human operators (albeit accepting that MBTs themselves currently suffer from internal space limitations, meaning that command and control of UGVs would probably have to be performed from supporting vehicles).

There is some overlap between MBTs and UGVs in terms of their technology and the purposes for which they are deployed – especially when crewed tanks are fitted with systems that have elements of automation, such as improved sensors and situational awareness, and the off-boarding of hard-kill and soft-kill countermeasures. In this context it seems highly likely that UGVs will play a complementary role within heavy armoured forces rather than have a realistic prospect of replacing MBTs.

Conclusion and Recommendations

A heavy armoured force remains the best option for high-intensity warfighting due to its combat power. While it exhibits vulnerabilities, so do all types of force structure, and facing a heavy armoured force compels an enemy to make difficult choices and places the burden of operational planning upon it if it hopes to be successful. Nevertheless, if the British Army were called on to engage in high-intensity warfighting without a significant number of MBTs, it would still be viable. A smaller, lighter, more autonomous force backed up by critical enablers in the form of ISTAR capabilities and indirect fires could maintain a high degree of lethality and pose difficult operational problems for any enemy force. However, the integration of many of these critical enablers must happen at battlegroup level and above, due to the limited capacity of company headquarters (even if assisted by advanced C2 tools that allow capabilities to be delegated) and due to the expense and inefficiency of distributing such capabilities evenly across small units. This analysis of the implications of using lighter forces raises questions about the ability of sub-units to perform offensive operations effectively due to a lack of combat power. Moreover, a warfighting capability built around a core medium armoured force would struggle to achieve its likely operational objectives were it to come up against a capable combined arms enemy force built around MBTs and heavy armour. While a medium or light force might be cheaper at a platform level, as well as more numerous and more distributed, ground combat units would suffer in the close fight, in both material and human terms. Medium armoured and light forces would be better seen as complementary to heavy armoured forces, with different formations able to cover one another's weaknesses and augment one another's capabilities when necessary.

The British Army faces several challenges in maximising the utility of its current armoured forces. They have suffered years of underinvestment, the Strategic Defence and Security Review 2010 having identified heavy armour as an area of low priority. Ambitions were set low, at:

> preserving the ability to reconstitute our levels of military capability in areas which are currently low priority, such as heavy armour – tanks – should international circumstances change. This means both holding in reserve certain sorts of equipment not needed for current operations and – importantly – maintaining core levels of training and experience among our

> personnel. This would provide us with the potential for expansion in the future.[122]

This approach has only recently begun to change amid decisions such as procuring Challenger 3 and Boxer, but many areas require investment. Consequently, there is a need to understand where resources and financial investment should be prioritised, since a complete, simultaneous overhaul of all the areas requiring modernisation is unrealistic. Critically, for heavy armour to be effective and survivable, the combined arms force as a whole needs to be able to conduct effective shaping of the battlespace to prevent saturation by enemy UAS and precision fires, and to be able to create sufficient uncertainty through deception that these enemy capabilities cannot target and attrit ground combat formations for decisive effect.

Ensuring that heavy armoured units have sufficient track miles and collective field training to maintain expertise at armoured warfare is more important than any technological advance. The major determinants of whether heavy forces will prove viable given the pressures put on them will be training, skill, and, critically, motivation – that is, the human element, the moral component and the professionalism of the force, which will culminate in the continued ability to fight in a truly combined arms manner. However, beyond this, changes and adaptations are still required. At the sub-unit level, technological improvements can improve situational awareness and contribute to better tactical employment, but will have to be integrated in such a way as to not compromise the existing strengths of MBTs: off-boarding of capabilities on to support vehicles and UGVs may prove a fruitful avenue of adoption and experimentation. Future MBT designs would benefit from prioritising mechanical simplicity and repairability, and from prioritising the resilience of parts that cannot easily be repaired in the field. If weight reduction to improve mobility over difficult terrain is to be considered when modernising platforms, this should not extend to adopting Soviet design principles that trade away platform or crew survivability (although the British defence establishment is in any case unlikely to go down that route given the pattern of increasing vehicle weight and a healthy appreciation of their duty of care compared with the Russian Armed Forces). The Challenger 3 upgrade provides an opportunity to improve the design in line with at least some of the principles outlined in this paper. A critical enabler with regard to turning these recommendations into reality is an overhaul of MBTs' interior ergonomics and the thorough integration of systems housed in the turret to ensure that crews benefit from technical improvements.

The MBTs and other heavy armoured vehicles at the core of combined arms formations remain important for both warfighting and other operations, as

122. HM Government, *Securing Britain in an Age of Uncertainty*, p. 34.

their unmatched combat power in the close fight helps ensure that a force can remain mobile when necessary. However, the balance must be shifted away from protection and towards a greater emphasis on mobility. This encompasses both strategic and operational mobility, since mobility contributes to survivability. The success of MBTs in the Gulf War set high cultural expectations regarding the survivability and offensive lethality of MBTs and heavy armoured forces organised, equipped, trained and employed as per the Western/NATO model of the time. These expectations need to be recalibrated, as individual tanks are increasingly vulnerable on the battlefield; nonetheless, well-trained, competently led and adequately equipped heavy armoured formations, supported by the correct enabling capabilities, are mobile, lethal and exceedingly difficult to counter.

Historical lessons about attrition in armoured warfare must also be relearned. Due to high maintenance requirements, crews may need to be rotated to prevent exhaustion and maintain a tempo of operations, and units may need to increase headcounts to ensure that some rotation is feasible. Heavy armoured forces need to get used to recovering and repairing damaged vehicles and replacing crew casualties as an inherent part of their operations. This also needs to be done in as dispersed a manner as possible in order to contend with an increasingly transparent battlefield and the threat of precision fires. It will be critical to maintain both recovery and repair units, as well as specialists, so that heavy armour can be quickly returned to its units after repair, with a particular emphasis on spare parts availability in the long term to ensure that vehicle losses do not translate into high rates of attrition.

Crew expertise in maintenance (both preventative and curative) is essential to reduce the burden on forward repair facilities run by dedicated mechanical engineers, and will also reduce the facilities' detectable signature, offering them greater protection.

All of these measures will need to go hand-in-hand with investments in track miles and training time: the traditional qualitative superiority of the human element can make the difference between a viable and non-viable armoured capability.

About the Author

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