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Leveraging Human–Machine Teaming

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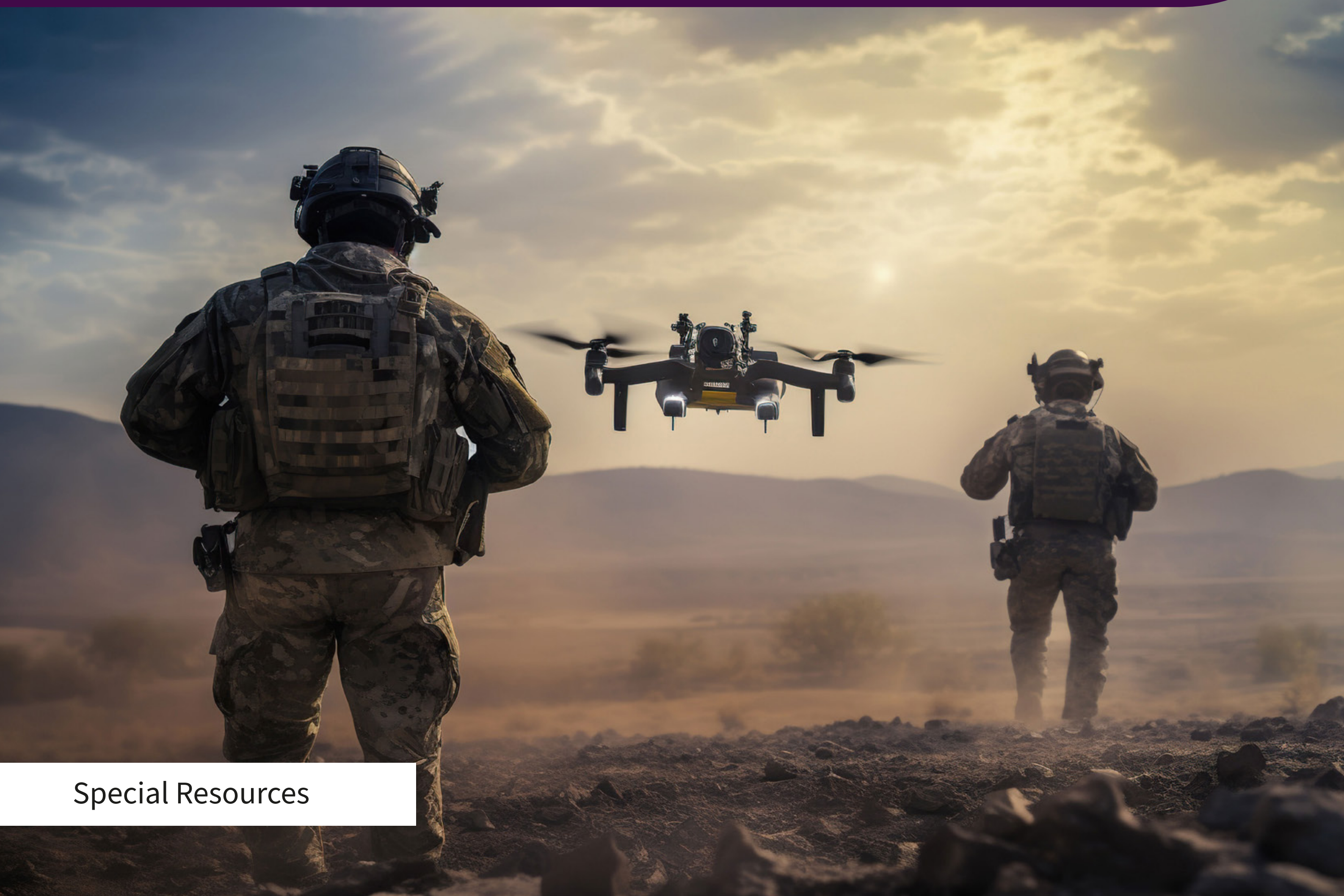

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Executive Summary

Interdependent human–machine teams will be a key component of future Western efforts to deter great power war and, if deterrence fails, win. The context in which decisions about human–machine teams and related technology are made is one in which the UK and the US face competitors that could reach parity in qualitative terms, and which possess selective advantages in mass stemming from both their industrial capacity and proximity to likely theatres of conflict, and from operational concepts specifically designed to target and defeat Western capabilities.

Despite these unprecedented challenges, the UK and the US possess considerable operational and military–technological asymmetries as a consequence of their democratic institutions, longstanding organisational biases, and experiences that are difficult for their competitors to deliberately replicate. Both countries trust their militaries to adapt and innovate at the lowest level. They have experience in combined arms operations, including in expeditionary environments. And neither country suffers from authoritarian pathologies such as endemic corruption, loyalty-based promotions or heavy censorship. Using these traits to shape the way the UK and US militaries develop, deploy and use capabilities will make it difficult for competitors to replicate Western countries' performance, even with the same underlying technology.

As part of a broader offset strategy informed by these asymmetries, the UK and US militaries should use human–machine collaboration (HMC) and human–machine teaming (HMT) to: demonstrate the potential to decrease the military, economic and political cost of war for the US and the UK and increase such costs for their adversaries; achieve decision advantage and impose dilemmas on adversaries; and generate awareness in denied environments. Given competing demands for finite resources, the US and UK militaries should focus, in the near term, on developing, acquiring and fielding a specific group of HMC and HMT capabilities and enablers necessary for accomplishing these goals. Such capabilities would be selected in terms of enabling activity within anti-access area denial bubbles. This specific task can be broken down into a number of sub-activities, including improving sensing, analysis, planning and decision-making, developing lower-cost and more attritable forces, uncrewed sustainment for expeditionary forces, enhancing deception, and leveraging HMC for predictive maintenance.

There are, however, caveats. First, unlike in the precision revolution, the West will not enjoy an obvious, persistent technological advantage in AI, autonomy, computing, and other militarily relevant science and technology fields. Second, a number of barriers that prevent the adoption and scaling of innovations will need to be overcome if the military potential of emerging technology is to be realised.

In this policy guide, the authors argue that advances in human–machine teaming will be crucial to delivering effective offsets to adversary advantages. To execute an offset strategy, militaries will need to develop technology and dedicate significant resources towards the development of new concepts of operations and approaches that treat the combination of human judgement and technological capabilities as central to success. This will be key to leveraging enduring organisational advantages.

This paper aims to serve as a primer and policy guide for policymakers, outlining the ways in which HMC and HMT make use of the specific approaches harnessed by Western states for technological change in service of these countries' asymmetrical advantages.

Introduction

Leveraging AI will be critical to delivering Western forces capable of competing and warfighting in the future operating environment, particularly against peer and near-peer competitors.[1] Notable figures ranging from the current First Sea Lord, Admiral Ben Key, to former US Deputy Secretary of Defense Bob Work have stressed that Western militaries must leverage innovation to overcome adversary capabilities.[2] However, Western militaries cannot assume technological overmatch against some plausible competitors, particularly China. Unlike in the Cold War era, when the West enjoyed clear qualitative advantages in several key areas such as command, control, communications, computers (C4) intelligence, surveillance, reconnaissance (ISR) and precision strike, in the future operating environment it could well find itself operating against China or a China-backed Russia – countries that can leverage a research and development base qualitatively comparable to those found in the West, particularly in areas such as AI.

Delivering an offset strategy against such an opponent therefore involves more than merely developing or acquiring emerging technology. Instead, that technology's impact will depend on how effectively it can be incorporated into concepts of operations that both accentuate the human and machine strengths of a friendly force and exacerbate the weaknesses of an opponent's force.

The militaries that best leverage autonomy and AI, then, will be those that best situate them within a warfighting system that includes concepts that guide their employment and organisational practices to generate forces that can properly use them.

This policy guide aims to prime policymakers on the factors that need to be considered to leverage human–machine collaboration (HMC) and human–machine teaming (HMT) for an offset strategy. Chapter I examines how the advent of AI and autonomy on the modern battlefield can change the conduct of warfare, and scopes both the opportunities that militaries can leverage and some of the challenges that they might face. Chapter II focuses on the specific operational objectives that militaries should pursue using HMC and HMT.

1. See, for example, US Department of Defense, 'Remarks by Deputy Secretary Work on Third Offset Strategy', 28 April 2016, <https://www.defence.gov/News/Speeches/Speech/Article/753482/remarks-by-deputy-secretary-work-on-third-offset-strategy/>, accessed 17 March 2023.
2. Neil Pooran, 'First Sea Lord Plans Royal Navy with "More Punch" in Coming Years', *PA Media*, 11 February 2022; Daniel Cebul, 'Bob Work has an Idea to Improve Artificial Intelligence', *C4ISRnet,* 23 January 2018, <https://www.c4isrnet.com/intel-geoint/2018/01/23/bob-work-has-an-idea-to-improve-artificial-intelligence/>, accessed 17 March 2023.

Chapter III concentrates on priority capabilities where HMC and HMT can deliver capabilities before 2030 and give Western militaries a competitive edge – and the enablers needed to create and field them effectively. Chapter IV outlines general principles that should guide the development of the capabilities described in Chapter III within Western militaries and defence establishments.

Purpose and Methodology

The purpose of the research project underlying this policy guide is to inform future defence approaches in the US and the UK and, between them, on HMC and HMT. It was carried out through a partnership between the Special Competitive Studies Project and RUSI, and through separate collaborations with the US Marine Warfighting Lab and the UK Ministry of Defence. The project brought together experts and practitioners from across the national security and emerging technology communities via a series of workshops held simultaneously in London and Washington, DC. The first of the three workshops, held on 10 November 2022, focused on identifying existing HMC and HMT capabilities and forecasting the development of capabilities that could realistically be fielded by 2030. The second workshop, held on 8 December 2022, focused on further refining the list of capabilities, and on identifying key enablers needed for the rapid incorporation of HMC and HMT into military activities and operations. The third workshop, held on 2 February 2023, focused on identifying implementation principles for HMC and HMT for the US Department of Defence and the UK Ministry of Defence. The results of these engagements are the basis of this policy guide, supplemented by a review of existing literature and consultations with experts.

I. What are Human–Machine Collaboration and Human–Machine Teaming?

HMC and HMT combine the human, the machine, and the interactions and interdependencies between them.[3] HMC focuses on optimising cognitive tasks, particularly decision-making, while HMT focuses on more effectively executing a wider range of complex tasks in physical spaces. Applications vary, and the most advanced applications will include elements of both.

Here, we define HMT as a complex military process with a feedback loop between the human and the machine which changes the behaviour of both. For example, if human operators deploy an uncrewed asset such as a UAV into a contested airspace with specific rules of engagement, the human's control over the UAV circumscribes its behaviour on the battlefield. Equally, the output the machine delivers independently into the feedback loop – for example, the ability to classify targets without direct intervention – can change the operator's decisions and subsequent actions. This is unlike a tool like artillery, which is basically linear: an operator knows what that tool can do and can predict outcomes (bar anomalies and miscalculations) accordingly – and the tool does not independently generate behaviour or information for which the operator must account.[4]

A core concept of HMC and HMT is that humans and machines have comparative advantages and excel in different areas.[5] Humans generally outperform machines on high-context tasks (those that focus on relationships between objects, rather

3. Margarita Konaev and Husanjot Chahal, 'Building Trust in Human-Machine Teams', *Tech Stream,* 18 February 2021, <https://www.brookings.edu/techstream/building-trust-in-human-machine-teams/>, accessed 18 November 2022.
4. For a useful primer on the distinction between tools and feedback loops, see Antoine Bousquet, *The Scientific Way of Warfare: Order and Chaos on the Battlefields of Modernity* (New York, NY: Columbia University Press, 2009), Chapter 7.
5. Tony Ojeda, 'The Algorithm – Human Tasks vs. Machine Tasks', *District Data Labs,* <https://www.districtdatalabs.com/the-algorithm-issue-34-human-tasks-vs-machine-tasks>, accessed 16 November 2022.

than on a particular focal consideration) and on various types of creative exploration. Machines, on the other hand, often outperform humans on tasks that require processing extremely large volumes of data, or which need a high degree of precision, speed or consistent repetition. Augmenting human weaknesses with machine strengths (and vice versa) can create interdependent HMTs that outperform both humans and machines individually.

Advances in AI-enabled HMC, in particular, could expand a military's ability to assess situations quickly, plan effectively and make decisions. A warfighter's mental bandwidth, like every human's, is limited. Military personnel collaborating with machines can break problems down into their component parts and allocate some tasks to be optimised, automated or performed at scale by a computer. Doing this removes some of the clutter that takes up so much cognitive bandwidth, freeing warfighters to focus on higher order processing, gaining situational awareness, understanding enemy plans and developing courses of action.[6] It can also allow military personnel to quickly and effectively perform cognitive tasks that would be difficult or impossible without machine collaboration, and especially without automation.

To incorporate HMC and HMT, militaries can identify bottlenecks in their operations, delegate tasks to machines as much as possible, and move humans to the boundaries of machine capabilities, where they can undertake the tasks that humans can perform more effectively than machines. Militaries that make the transition to HMC and HMT could make decisions and conduct operations more effectively, more quickly, and on a larger scale than organisations that do not, all at a lower human cost.[7] Though not a panacea, AI can considerably reduce issues surrounding span of control, much as automation does in the context of integrated air and missile defence.[8] To the extent that functions associated with staffs can be automated, staffs can be shrunk – enabling the control of more capabilities at lower echelons. Robots can perform tasks that are too dangerous for humans, such as bomb disposal, generating ISR or attacking in heavily denied airspace, allowing units to perform operations that would not otherwise be feasible.[9]

6. See Center for Computational Thinking, Carnegie Mellon University, 'What is Computational Thinking?', <https://www.cs.cmu.edu/~CompThink/>, accessed 18 November 2022.
7. Marco Iansiti and Karim R Lakhani, 'Competing in the Age of AI', *Harvard Business Review* (January–February 2020), <https://hbr.org/2020/01/competing-in-the-age-of-ai>, accessed 11 October 2022.
8. Paul Scharre, *Army of None: Autonomous Weapons and the Future of War* (New York, NY: W W Norton, 2018).
9. On the use of robots for bomb disposal, see Elliot Gardner, 'Bomb Disposal Robots: The New Frontier', *Army Technology*, 2 January 2019, <https://www.army-technology.com/features/bomb-disposal-robots-the-new-frontier/>, accessed 19 March 2022. On attritable UAVs as eyes forward, see Thomas Hamilton and David Ochmanek, *Operating Low-Cost, Reusable Unmanned Aerial Vehicles in Contested Environments: Preliminary Evaluation of Operational Concepts* (Santa Monica, CA: RAND, 2020).

HMC and HMT are not synonymous with full autonomy, which lacks the machine–human interdependence that is HMC and HMT's defining characteristic. Full autonomy implies systems making decisions with no human intervention beyond design and initiation. HMTs might have autonomous components, but removing one human-to-human or human-to-machine relationship does not eliminate the need for teamwork between humans and machines – and it will not eliminate humans. Rather, it changes where the boundaries within the system lie.

However, HMC and HMT rely on a degree of autonomy to be effective, especially during time-compressed situations or high-intensity conflicts. HMC and HMT can thus serve as stepping stones towards, or catalysts for, driving the pursuit of greater autonomy by helping develop and test capabilities, human–machine interfaces, and the military's ability to employ semi-autonomous or autonomous systems effectively and responsibly.

How Will HMC and HMT Affect Warfighting?

Effect on Casualty Rates

In general, states are likely to increase the use of machines to minimise casualties and improve operational effectiveness. However, because states have different levels of resources and experience with autonomous technology development, some will significantly outperform others with regard to HMT.[10] If one state manages to overwhelm or bypass its adversary's machines, it is likely to continue on to attack the human elements of the military, or even the civilian population. This would result in a significant imbalance in casualties between the combatant states, with the advantaged side sustaining few casualties and the disadvantaged side sustaining many.

In conflicts with more symmetrical HMT usage, the number of casualties that the combatant states sustain would depend on the circumstances of that specific conflict. During limited wars, states could be more likely to seek a negotiated outcome after a large portion of their machines have been neutralised or destroyed, but before they have lost many military personnel and civilians. During more total wars, especially if large numbers of people are mobilised (as

10. Margarita Konaev and Tate Nurkin, *Eye to Eye in AI: Developing Artificial Intelligence for National Security and Defense* (Washington, DC: Atlantic Council, 2022), pp. 18–19; Justin Lynch et al., 'Human-Machine Teaming in Warfare', 2-2-2 SCSP Newsletter, 30 June 2022, <https://scsp222.substack.com/p/human-machine-teaming-in-warfare>, accessed 7 February 2023.

is currently being seen in Ukraine), states are likely to continue fighting and thus experience casualty levels similar to those seen in wars without HMT.

There are some caveats here. First, fewer human operators should not be seen as being synonymous with smaller militaries in general – the repair, combat support and sustainment requirements of keeping machines operational could create new roles that are not easily automated, or whose requirements expand with the number of machines. While this could still result in smaller militaries, such an outcome should not be assumed.

Second, completely symmetrical HMT usage – whether from a capabilities or operational employment standpoint – is unrealistic. The rate of adoption of new technologies, capabilities and operating concepts across militaries – and within their organisation – will be uneven, leading to different rates of change in tempo and scale of operations. Boundaries of adoption across a military's organisations can create friction, and limit the ability of one state to leverage the full potential of a technology or capability relative to another state.[11] New technologies will also have differential effects on the components of a force, which will likely lead to different levels of hybridisation of HMT and traditional capabilities within individual states.

Third, HMT does not necessarily entail the displacement of existing capabilities. New technologies often change forces by creating arms systems that combine new and existing capabilities. The armoured revolution, for example, did not end the role of infantry, although it did emphasise making them more mobile, and reduced their number as a proportion of the overall force. The future battlefield we might envision, then, is not necessarily one in which today's platforms and personnel are entirely absent, but one in which, because they are enabled by HMC/HMT, the proportion of the force that they represent is lower.[12]

Fourth, actors that cannot adopt a given mode of warfare will seek to offset it – as those actors incapable of fighting industrial-age warfare did by adopting guerrilla methods.[13] If a smaller cohort of human operators becomes the tactical/operational centre of gravity in the context of HMT, adversaries will have incentives to target them. If this is tactically difficult, the weaker party may resort to means off the battlefield, such as attacking military residential facilities with ballistic missiles (as Iraqi forces did with US barracks in Saudi Arabia in 1991).[14] Alternatively, insurgents who cannot easily target their opponents on

11. Michael C Horowitz, *The Diffusion of Military Power* (Princeton, CA: Princeton University Press, 2010).
12. For example, consider the US Navy's future fleet design, which involves 373 crewed ships and 155 uncrewed vessels. See Sam LaGrone, 'Navy's Force Design 2045 Plans for 373 Ship Fleet, 150 Unmanned Vessels', *USNI News*, 26 July 2022, <https://news.usni.org/2022/07/26/navys-force-design-2045-plans-for-373-ship-fleet-150-unmanned-vessels>, accessed 15 February 2023.
13. Ivan Arreguín-Toft, *How the Weak Win Wars* (Cambridge: Cambridge University Press, 2005).
14. R W Apple Jr, 'Scud Attack; Scud Missile Hits a U.S. Barracks, Killing 27', *New York Times*, 25 February 1991.

the battlefield might pursue systematic assassination campaigns, as in Chechnya and Afghanistan. Increasing the number of digital systems will also increase the number of potential cyber vulnerabilities and attack surfaces adversaries might exploit.[15]

Finally, some experiments have shown a tendency for automated swarms to fight each other to a stalemate. In such circumstances, the deciding factor may well be direct engagements between the human elements of two HMTs.[16]

Increases in Operational and Strategic Risk Appetite

As HMT capabilities improve, US and UK militaries are likely to shift operational risk to attritable machines whenever possible or appropriate.[17] With this change, commanders can execute previously unacceptable manoeuvres, assured that their own combat losses will mostly consist of machines, not human lives. Commanders could also be expected to fight more determined defences if they were to expect that many of the losses incurred in so doing would be of machines.

Restoration of Mass

HMT can help militaries employ lower-cost, easier-to-manufacture machines to overcome complex challenges. Single, exquisite platforms have operational strengths, but also considerable limitations, including lengthy production timelines and high manufacturing costs. Although exquisite systems are by no means obsolete, their capacity would be strained by diverse swarms of inexpensive systems. In one of the first known drone swarm attacks, Houthi rebels in 2019 used 25 drones and cruise missiles to attack Saudi oil processing facilities. These facilities were defended by German Skyguard SAM missiles, which were completely ineffective against the drone swarm.[18] Additionally, when the Saudi air defenders did adjust to the UAV threat, they were forced to expend very expensive interceptors on cheap uncrewed aerial systems.[19] Mass itself, however, will not replace large and complex platforms. Decision-makers will need to consider the appropriate mix of attritable and complex capabilities.

15. J C Humphrey, 'Casualty Management: Scud Missile Attack, Dhahran, Saudi Arabia', *Military Medicine* (Vol. 164, No. 5, May 1999), pp. 322–26; John Arquilla, *Insurgents, Bandits and Raiders: How the Masters of Irregular Warfare Shaped Our World* (Chicago, IL: Ivan R Dee, 2011).
16. Scharre, *Army of None*.
17. John D Winkler et al., *Reflections on the Future of Warfare and Implications for Personnel Policies of the US Department of Defense* (Santa Monica, CA: RAND, 2019), pp. 16–20.
18. Natasha Turak, 'How Saudi Arabia Failed to Protect Itself from Drone and Missile Attacks Despite Billions Spent on Defense Systems', *CNBC*, updated 23 September 2019.
19. Jack Watling and Sidharth Kaushal, 'The Democratisation of Precision Strike in the Nagorno-Karabakh Conflict', *RUSI Commentary*, 22 October 2020.

Massed machines, assigned tasks by their human teammates, could overwhelm traditional defences, often at a relatively smaller cost in human casualties compared to more traditional offensive operations,[20] such as Russia's use of Shahed-136 drones to exhaust Ukraine's SAM stockpiles.[21] Machines could also serve as the 'eyes and ears' of their human teammates, particularly in urban warfare, by accessing hard-to-reach places, leveraging many different viewpoints, and taking risks that otherwise humans would have to take.[22] One example is Elbit System's LANIUS drone, a loitering munition outfitted for urban combat. These come complete with beyond-line-of-sight ISR and attack capabilities, an HMT mode with minimal user interaction[23] and a top speed of 45 mph, which gives the user the option for strict ISR use, or the ability to attack a target.

There may be an interaction here between the opportunities afforded by AI and trends that decrease the manufacturing costs of many capabilities, such as UAVs. For example, additive manufacturing may reduce the production timelines for missiles from months to weeks, and drive costs down exponentially.[24] If this is the case, then much of the cost of producing a system might be determined by its sensor package and the necessary levels of integration (though the requirements of physical movement in any domain and the costs entailed will remain). This could drive a substantial divergence between the cost of simpler single-capability systems and larger complex platforms. The former can nonetheless be networked to produce complex results – for example, if multiple platforms with simple sensors cross-reference data to create a single high-fidelity operating picture.[25]

HMT may also change the ratio of humans to machines needed to perform certain tasks, with implications for mass in general. Today, in most cases, many warfighters collectively control one platform, such as a ship. While that relationship is unlikely to vanish, at least two other human–machine relationships are developing that could begin to chip away at the dominant warfighter–platform relationship. One such mode is a small number of warfighters controlling many machines, as seen in examples such as the Defense Advanced Research Projects

20. T X Hammes, 'The Future of Warfare: Small, Many, Smart vs. Few and Exquisite?', *War on the Rocks*, 16 July 2014.
21. Justin Bronk, Nick Reynolds and Jack Watling, 'The Russian Air War and the Ukrainian Requirements for Air Defence', RUSI Special Report, 7 November 2022, p. 58.
22. Liam Collins and Harrison 'Brandon' Morgan, 'Affordable, Abundant, and Autonomous: The Future of Ground Warfare', *War on the Rocks*, 21 April 2020.
23. Elbit Systems, 'LANIUS: Drone-Based Loitering Munition for Complex Environments', <https://elbitsystems.com/product/lanius/>, accessed 15 April 2023.
24. See Matt Kremenetsky, 'China's Largest Missile Maker Using 3D Printing to Accelerate Production', *3DPrint.com*, 24 March 2022, <https://3dprint.com/289915/chinas-largest-missile-maker-using-3d-printing-to-accelerate-production/>, accessed 2 July 2022.
25. You He, 'Mission-Driven Autonomous Perception and Fusion Based on UAV Swarm', *Chinese Journal of Aeronautics* (Vol. 33, No. 11, 2020), pp. 2831–34.

Agency's (DARPA) OFFSET programme, which seeks to enable small infantry teams to act as controllers of up to 250 uncrewed air and ground vehicles each.[26]

Another, less discussed, relationship is one in which a small number of developers create applications that optimise the performance of many machines and warfighters. This HMC relationship has recently been seen as GIS Art for Artillery (ARTA), a Ukrainian military software program used to distribute fire requests. The software enables multi-gun, multi-munition fire missions at a much faster rate than traditional targeting processes by allowing a machine to develop, interpret and distribute guidance to operators.[27]

The potential to combine limited numbers of more specialised warfighters with large numbers of less expensive, uncrewed machines might incentivise a shift away from force structures based around more limited numbers of exquisite platforms. We might see the development of force structures that combine a limited number of expensive platforms and increasing numbers of cheaper, uninhabited platforms that provide mass.[28] This would enable smaller units to cover wider frontages both on land and at sea – a belief central to concepts like the US Navy's Distributed Maritime Operations framework.[29] This approach will be important, because to survive on a battlefield characterised by long-range fires, forces need to disperse – but to disperse, they need mass.

It is possible that this vision will fail to be realised in all areas. In some cases, machines sufficiently capable of performing important tasks might be expensive, and therefore unlikely to be risked.[30] The costs of platforms in any area often decrease with economies of scale, but the UK and US militaries still must determine whether machines should be viewed primarily as cheap munitions and sources of ISR, or as genuine complements to inhabited platforms. Drones can also experience high attrition rates, even in the absence of sophisticated counter-drone or counter-autonomy systems, and serve as new attack surfaces. With the proliferation of different types of machines, and an increase in their numbers, militaries will need to account for new vulnerabilities while investing in counter-drone technologies that are able to improve faster than drone technology.

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26. Defense Advanced Research Projects Agency, 'OFFSET Swarms Take Flight in Final Field Experiment', 9 December 2021, <https://www.darpa.mil/news-events/2021-12-09>, accessed 8 March 2023.
27. Charlie Parker, 'Uber-Style Technology Helped Ukraine to Destroy Russian Battalion', *The Times,* 14 May 2022.
28. T X Hammes, 'Technological Change and the Fourth Industrial Revolution', *The Cove,* 14 August 2018, <https://cove.army.gov.au/article/technological-change-and-fourth-industrial-revolution-tx-hammes>, accessed 9 March 2023.
29. Richard Mosier, 'Distributed Maritime Operations – Becoming Hard-to-Find', *CIMSEC,* 12 May 2022, <https://cimsec.org/distributed-maritime-operations-hard-to-find/>, accessed 9 March 2023.
30. Justin Bronk and Jack Watling, *Necessary Heresies: Challenging the Narratives Distorting Contemporary UK Defence,* RUSI Whitehall Paper 99 (Abingdon: Routledge, 2021), pp. 49–60.

Force Composition

The incorporation of HMC and HMT will raise questions about the degree of training and specialisation needed for select military tasks. The use of machines will almost certainly require greater expertise for some tasks, driving the need for new career fields in system integration, software development, AI and other areas. Other tasks, however, may require less training when machines help humans perform them. The conflict in Ukraine has shown how non-specialist units can gain lethality by leveraging technology. Other tasks and the personnel associated with them may vanish entirely, as HMC and HMT drive changes in operational concepts and force structure. If the future force involves a limited number of specialists and a much larger number of machines, the emphasis ought to be on recruiting or developing individuals with requisite skills to fill niche roles. If, on the other hand, HMT enables a levée en masse, then greater emphasis might be placed on procuring capabilities that non-specialist personnel can use.

Increased Battlefield Awareness

HMC and HMT have the potential to increase battlefield awareness in several ways. First, they can expand the number, reach, persistence and type of sensors that the US and UK militaries field and access. For example, machine learning (ML) has enabled the sifting of false positives needed for the acoustic detection of targets like UAVs and helicopters.[31] Second, ML can enable data from existing sensors to be more effectively exploited. For instance, low-frequency active sonar such as that used on T-AGOS ships can detect submarines at very long ranges, but produces too many false positives to be used without incorporating other data. This is another area where ML, in particular, can enable militaries to use the data their sensors are already able to gather, simply by changing the software.[32]

Finally, non-military sources of data gathering and transmission can become usable. Analysts are increasingly able to absorb and integrate data from non-military sources, such as commercially purchased and open-source datasets, as well as information reported by civilians in combat zones.[33] This volume of data exceeds what human analysts can process.[34] As AI-enabled software increases the speed and quality of analysis by HMTs and the quality of its presentation to

31. Pietro Casablanca and You Zhang, 'Acoustic-Based UAV Detection Using Late Fusion of Deep Neural Networks', *Drones 2021* (Vol. 5, No. 3, June 2021).
32. Bryan Clark, *The Emerging Era in Undersea Warfare* (Washington, DC: CSBA, 2015), pp. 15–16.
33. Robert Work and Tara Murphy Dougherty, 'It's Time for the Pentagon to Take Data Principles More Seriously', *War on the Rocks*, 6 October 2020; Gillian Tett, 'Inside Ukraine's Open-Source War', *Financial Times,* 21 July 2022.
34. Anna Knack et al., *Human-Machine Teaming in Intelligence Analysis* (London: CETaS, 2022), p. 7.

military leaders, battlefield awareness and the ability to make data-driven decisions should also improve. Combined with the proliferation of long-range strike capabilities, this could increasingly remove sanctuaries and staging areas from future battlefields.

The ability of fielded forces to operate would rely on a combination of new forms of deception, such as the 'poisoning' and evasion approaches used to confound ML algorithms, superior fires, and degrading enemy logistics. Such approaches to deception hinge on feeding opposing algorithms bad data or altering the image presented to them in a way that exploits a known tendency to misclassify certain inputs. For example, deep learning models used in cars can be induced to misclassify road signs through minor alterations, such as adding stickers to the signs.[35] Even as AI continues to advance, it is likely that it will remain possible to deceive it, including in ways that would not deceive human operators. Moreover, blending in to the civilian environment through adaptations like containerising missiles and UAV launch platforms may obviate the risk of detection somewhat – but would increase the risk of civilian casualties.[36] In effect, then, the central focus of deception operations in an era dominated by HMC and pervasive ISR would be hiding in plain sight. It would not be possible to avoid detection, but militaries could prevent their opponents from turning data into useful knowledge.

Changes to Command and Control

HMC and HMT could make it possible for smaller formations to operate with greater levels of independence. Automating staff functions can empower units that lack large staffs. Without expanding the size of the staff or increasing individuals' cognitive load, HMC could assist with operational planning, logistics, adjacent unit coordination, and the deconfliction and tasking of assets historically held by higher echelons.[37] This could be of use in information-denied environments where reach-back communications to higher echelons are not always available. A corollary would be that relatively junior officers would be entrusted with greater authority, potentially generating a training need.

It is also possible, however, that HMC and HMT would help centralise command. Militaries such as China's People's Liberation Army (PLA) have, despite some exceptions, emphasised the use of AI-enabled decision aids that help higher echelons of command solve information bottlenecks and exercise more direct

35. Kevin Eykholt et al., 'Robust Physical-World Attacks on Deep Learning Models', *Arxiv*, 10 April 2018, <https://arxiv.org/abs/1707.08945>, accessed 15 February 2023.
36. T X Hammes, 'Technological Change and the Fourth Industrial Revolution', in George P Shultz, Jim Hoagland and James Timbie (eds), *Beyond Disruption: Technology's Challenge to Governance* (Stanford, CA: Hoover Institution Press, 2018).
37. Clark et al., *Mosaic Warfare*, pp. 29–40.

control over formations. Confident that resilient communications are achievable and that AI will reduce the risk of information overload, the PLA envisions a high degree of synchronisation through giving theatre-level commanders control of tactical formations.[38]

Which view of command holds greater promise remains to be seen. The choice appears to be between flexible, laterally organised formations that aim for tactical flexibility, and those that deliver victory through tight operational-level coordination. Militaries like the PLA appear to be betting heavily on the latter form of command and control, which could represent a challenge if HMT enables greater local control by commanders but more uncertainty at the systemic level. This is precisely what has occurred in the context of algorithmic trading in financial markets, where the ability to routinise many actions has led to more individual control (and thus complex trading behaviour), in turn leading to greater complexity and uncertainty at the market level.[39]

38. Jeffrey Engstrom, *Systems Confrontation and System Destruction Warfare: How the Chinese People's Liberation Army Seeks to Wage Modern Warfare* (Santa Monica, CA: RAND, 2013).
39. Martin Hilbert and David Darmon, 'How Complexity and Uncertainty Grew with Algorithmic Trading', *Entropy* (Vol. 22, No. 5, April 2020), p. 499.

II. Objectives of HMC and HMT Integration in Defence

As discussed above, there is not always a linear relationship between HMC and HMT and a specific approach to warfighting – how a new technology manifests is mediated by factors including national and organisational culture. Some militaries might use HMC and HMT to enable decentralised activity, for example, while others might see it as a means of ensuring tight central control over a distributed force. This chapter addresses how the UK and the US can best leverage HMC and HMT to enhance the advantages of their own approach to warfare, and to undercut the ways in which opponents might harness the revolution in AI and autonomy.

The challenge the UK and the US would face in the eventuality of direct combat with peer competitors, or with near-peer competitors such as China or Russia, is dissimilar to that posed by previous opponents against which the offset strategies of the past century were designed. Against the Soviet Union, the Second Offset leveraged modern precision-strike capabilities to enhance fairly tested concepts of interdiction through airpower.[40] Its success was predicated on building and maintaining technological superiority.

By contrast, an opponent like China is likely to become a challenger in terms of both mass and platform quality.[41] The Pentagon's 2020 China Military Power Report assessed China as having achieved parity with or superiority over the US in several areas, including integrated air defences and land-based precision strike.[42] China enjoys an increasingly competitive position more broadly, for example in areas such as research citations: in 2022, Japan's National Institute of Science and Technology Policy estimated that China accounted for over 27%

40. Douglas W Skinner, *Airland Battle Doctrine* (Washington, DC: Center for Naval Analysis, 1988).
41. Newer Chinese platforms such as the Type 055 Cruiser, which is equipped with an AESA radar and the capacity to launch both cruise and ballistic missiles, arguably outmatch direct counterparts such as the *Ticonderoga* class. None of this is to suggest that the Chinese system – riven by several structural flaws like the inefficiency of state-owned enterprises – is destined for economic dominance. However, platform superiority cannot be assumed.
42. Department of Defense (DoD), *Military and Security Developments Involving the People's Republic of China: Annual Report to Congress* (Washington, DC: DoD, 2020), p. 7.

of the world's most frequently cited research that year, overtaking the US.[43] Technological overmatch cannot be the assumed basis for an offset strategy in the same way that it was against a very different opponent in the previous century.

As a result, the UK, the US and their allies should prepare to overcome an opponent that has near parity in qualitative terms, advantages in both the industrial capacity to replace losses and proximity to likely theatres of conflict, and operational concepts specifically designed to target Western capabilities and operational concepts.[44]

The US and UK militaries should work with allies to use HMC and HMT to pursue the following objectives as part of a broader offset strategy:

- **Demonstrate the potential to decrease the human, economic and political cost of war for the US and the UK and increase such costs for their adversaries**. In operating environments in which it is increasingly difficult to gain access or generate mass, shifting operational risk from humans to machines would change the relative cost. Perhaps even more importantly, as US and UK commanders gain freedom of manoeuvre and increase their ability to penetrate contested spaces, the cost of war for the adversary would increase. This would help address any perceptions that states waging expeditionary wars for less than existential ends have limited resolve. Such assessments, accurate or not, may lead an opponent to conclude that all they need to achieve the withdrawal of Western forces is the capacity to inflict a sufficient level of attrition. Even if this assessment of limited resolve is not accurate, the fact that it is held represents a challenge for deterrence, which ultimately hinges on what US and UK competitors believe. Therefore, demonstrating the capacity to limit human costs undercuts a major pillar of opponents' theories of victory – and thus reinforces deterrence.
- **Achieve decision advantage and impose dilemmas on adversaries**. The use of HMC and HMT allows militaries to increase the degree of operational and tactical unpredictability which their adversaries – with or without their own HMC and HMT capabilities – must address. HMC could improve and accelerate sensing, planning and decision-making and generate more options for action. HMT, having shifted operational risk from humans to machines, would also present commanders with a new and more favourable risk–benefit calculus, and increase the number of options. This is especially true if the machines in question are cheaper single-purpose platforms that can be more readily

43. Ryosuke Matsuzoe, 'China Tops U.S. in Quantity and Quality of Scientific Papers', *Nikkei Asia*, 10 August 2022, <https://asia.nikkei.com/Business/Science/China-tops-U.S.-in-quantity-and-quality-of-scientific-papers>, accessed 17 April 2023.
44. Fenella McGerty and Meia Nouwens, 'China's Military Modernization Spurs Growth for State-Owned Enterprises', *Defense News*, 8 August 2022.

expended than comparable crewed assets – for example, an extra-large uncrewed underwater vehicle (XLUUV) as opposed to a submarine.[45]

Of course, if one assumes technological parity with opponents, success will likely be a function of organisational capacity, rather than technical skill. Organisations better able to interact with the machines at their disposal and to understand the interactions between individuals and machines on the other side are likely to succeed. We might consider how, for example, both Russian and Ukrainian forces have sought to confound one another's targeting in often subtle ways, for example causing marginal adjustments to GPS coordinates in one another's systems. Winning engagements has been a function of the ability to identify adversary-induced technical errors early and compensate for them – tasks that will depend on the human component of a force.

- **Generate awareness in denied environments**. The US and UK militaries need to use HMC and HMT to better understand their adversaries' objectives, intentions and capabilities in order to be able to learn and adapt more quickly in a rapidly evolving operational environment. This may need to occur in the context of information denial, particularly at the tactical level.

  At the level of strategic analysis, possible applications might include using deep learning to spot unique or anomalous cases (something traditional deductive models struggle with) or sift large volumes of primary data for patterns.[46] The latter function may be particularly significant, as strategic intelligence failures are usually the product of surplus information, rather than a dearth of it.

  At the tactical level, autonomy and AI can improve situational awareness in several ways. Autonomous sensors can lie dormant longer than humans, without their attention level decreasing over time and without the need to rest or move. This further frees up personnel for tasks that must be carried out by humans. Autonomous platforms can enable detection at long ranges using sensors such as low-frequency active sonar that currently produce too many false positives to be used alone, and they can also enable targeting based on prediction rather than observation. Furthermore, autonomous

45. Consider, for example, the likely cost differentials between the Royal Navy's SSNs and its planned *Manta*-class XLUUV. See *NavyLookout*, 'Manta – The Royal Navy Gets its First Extra Large Autonomous Submarine', 31 March 2020, <https://www.navylookout.com/manta-the-royal-navy-gets-its-first-extra-large-autonomous-submarine/>, accessed 15 February 2023.
46. Agrawal, Gans and Goldfarb, *Prediction Machines*, pp. 20–30; Roberta Wohlstetter, *Pearl Harbor: Warning and Decision* (Stanford, CA: Stanford University Press, 1966).

platforms carrying sensors can be risked in situations where crewed systems cannot. Another advantage of autonomous systems is that high-risk surveillance that might not be risked with human assets can be countenanced with machine assets. Though they may be lost in combat, such assets are both less costly than crewed ones and, in peacetime, their loss may not be as diplomatically challenging. For example, incidents like the Iranian downing of an RQ-4 Global Hawk in 2019 or the recent confusion surrounding the PLA's surveillance balloon might be juxtaposed with the downing of Gary Powers' U-2 or the EP-3 incident.[47]

HMC and HMT will help to achieve these broad objectives by helping to accomplish the following six military objectives:

1. **Absorb and effectively use ever-increasing volumes of data at the operational and strategic levels**. The proliferation of military, commercial and privately owned sensors, alongside platforms that encourage data sharing for commercial services and rising internet connectivity, have increased the volume, velocity and diversity of data to a level that humans in operations centres, staff and command positions can no longer track and process. Properly programmed and supervised machines, enabled by a data-sharing regime, are well suited to augment human bandwidth, generating better situational awareness and recommending plans. This could be especially critical in the early phases of a conflict, before circumstances force both sides to adjust, information becomes more contested and old data becomes a wasting asset. The side that begins a conflict with the best available data can shape the conflict's early, decisive phase. HMC can enable the exploitation of data already within the joint force – much of which is wasted.[48] There is a second way that HMC and HMT can enhance the situational awareness of human operators: by enabling them to get more out of existing sensors. Many existing sensors have the ability to track elusive targets, but they generate false positives – something that can be overcome with ML, which is already being applied to tasks such as radar signal processing.[49] A third way in which machines could enable the use of increasingly advanced commercial capabilities to transfer data is by providing encryption at speed and at a level that would allow data to pass through a commercial network safely. This is already the case with data passed on from

47. Joshua Berlinger et al., 'Iran Shoots Down US Drone Aircraft, Raising Tensions Further in Strait of Hormuz', *CNN,* 30 June 2019; Juliana Suess, 'The Chinese Surveillance Balloon: Blown Out of Proportion?', *RUSI Commentary*, 6 February 2023.
48. Mark Owen, Katie Rainey and Rachel Volner, 'How AI is Shaping Naval Intelligence, Surveillance, and Reconnaissance', in Sam J Tangredi and George V Galdorisi (eds), *AI at War: How Big Data, AI and Machine Learning are Changing Naval Combat* (Annapolis, MD: Naval Institute Press, 2021), p. 168.
49. Qiang Guo, Xin Yu and Ruan Guoqinq, 'LPI Radar Waveform Recognition Based on Deep Convolutional Neural Network Transfer Learning', *Symmetry* (Vol. 11, No. 4, April 2019), p. 540.

the F-35, for example, and could be generalised. Finally, human and autonomous asset teaming can enable more aggressive data gathering in peacetime.

2. **Develop a faster, higher-quality decision-making cycle**. Machines can accelerate decision-making cycles – often framed as observe–orient–decide–act (OODA) loops in military circles – to grant tactical advantage, create more time for planning, and react more quickly to adversary operations or adaptations. Achieving advantage requires controlling tempo and accelerating it where that grants advantage, not just accelerating tempo across the board.
3. **Automate routine actions and processes to augment human decision-making**. Several tasks for field operations, operations centres, planning and sustainment require limited decision-making skill, but absorb a great deal of time. Automating and integrating these processes at scale could free up human bandwidth for more complex tasks, potentially reduce the number of people required for certain components of expeditionary operations, accelerate the planning process, and augment the quality and range of human decision-making.
4. **Generate physical and virtual effects at scale in heavily denied environments**. The proliferation of sensors, analytical tools, precision-guided munitions and non-kinetic payloads are fundamentally altering the hider–finder contest, placing traditional massed forces at risk. HMT has the potential to generate mass that can operate in such environments through the employment of prepositioned machines, attritable forces and complex manoeuvres.
5. **Overwhelm adversary defences with lower risk to friendly forces**. Some adversaries have developed anti-access area denial (A2/AD) concepts and capabilities that challenge US and UK power projection. Massed machines, assigned tasks by their human teammates, could overwhelm traditional defences through a combination of sheer volume and attacking on many vectors simultaneously, often at a lower cost in human casualties compared with more traditional offensive operations. They might also supplement crewed platforms by acting as decoys or stand-in jammers.[50] Machines could also serve as the 'eyes and ears' of their human teammates, particularly in urban warfare, by helping them gain more information about their environment and taking risks in their place.
6. **Defeat layered standoff**. Power projection, particularly in the Indo-Pacific, depends on a limited number of critical nodes including aircraft carriers, airbases and ports. Over the past few decades, adversaries have progressively developed systems to put traditional modes of power projection at risk through the integration of air defence systems and long-range precision strike capabilities designed to counter Western strengths in manoeuvre. Restoring

50. Bryan Clark, Mark Gunzinger and Jesse Sloman, *Winning in the Gray Zone: Using Electromagnetic Warfare to Regain Escalation Dominance* (Washington, DC: CSBA, 2017).

freedom of manoeuvre would require the US and the UK to prevent components of a given system from operating coherently by degrading the system's functionality. This can be achieved by presenting both platforms and operators with a tempo of activity that they cannot match, and by stressing critical system dependencies – including communication modes, avenues for resupply and operator wellbeing – beyond the point of effectiveness. The more dilemmas a system is presented with, the greater the likelihood that its functionality degrades. HMT can also enable forces that are dispersed and capable of dynamically reconstituting kill chains to mitigate single points of failure, and thus deny opponents the opportunity to benefit from the effects of layered standoff. HMT and HMC can enable the fielding of cheaper, more attritable assets to maintain a constant tempo of pressure, allow kill chains to close more rapidly to facilitate responsive targeting, abet assessments of system functionality, and allow the use of predictive analytics to maintain responsive and agile logistics systems to facilitate a higher tempo of activity.

III. Capabilities and Enablers Required to Accomplish These Goals

Given competing demands for finite resources, the US and UK militaries should focus, in the near term, on developing, acquiring and fielding a specific group of HMC and HMT capabilities necessary for accomplishing the goals described above. There are tools to improve sensing, analysis, planning and decision-making – for example, to incorporate real-time intelligence and running estimates into planning and simulations. Lower-cost sensing and attack platforms could develop attritable forces, manufactured and subsequently employed at lower cost, that pose a lower level of risk for human operators. By generating more mass, these could facilitate simultaneous attacks in greater numbers, with the desired effect of overwhelming adversary defences. Another use is the uncrewed sustainment of expeditionary forces in contested environments, which could improve the resilience of resupply and increase survivability. Further, (partially) automated computer network attacks can be used against adversary data links and ISR platforms, enhancing operational deception by leading adversary forces astray and disrupting – or even derailing – their operations. Finally, HMC could be leveraged for predictive maintenance: the automation of a range of maintenance and back-office functions could enable more rapid and efficient operations and free up human capacity for other tasks. These are discussed in detail below.

Priority Military Capabilities

Tools to Improve Sensing, Analysis, Planning and Decision-Making

The US and UK militaries could use HMC to accelerate the pace of planning, integrate real-time intelligence and running estimates into planning and simulations, generate more options in a given period of time, and more effectively evaluate the likely outcome of an action.

- **Imperative**: Political leaders and military commanders face a volume, velocity and diversity of data greater than the human ability to process and understand it; this disparity is only likely to increase.
- **Promise**: Machines offer the opportunity to augment human bandwidth to not only handle this data, but to generate more (and better) courses of action than human planners alone can create, and to help integrate perception and planning across agencies. Machines can process vast amounts and types of data, aggregate it and turn it into useful information, and prioritise it for human decision-making. Machines, particularly unsupervised ML, can also identify novel patterns that humans have not seen (and which, in many cases, humans are unable to identify).[51] Machines can also facilitate the resilient data-sharing networks needed to transmit data in contested environments. For example, NASA's development of cognitive communications is one avenue for a resilient satellite-based communications system. NASA envisions gathering data from a network of satellites and their collective environment to overcome communication challenges with minimal human interaction.
- **Desired effect**: Using tools in these ways would improve situational awareness and empower a planning process that is faster, more creative, generates more options, and is better suited to creating a plan optimised for a specific challenge. The ability to plan with smaller headquarters or staff would also enable smaller units, operating in a fragmented and information-denied battlefield, to conduct operations based on horizontal collaboration with those units they can communicate with, rather than relying on top-down direction from higher echelons that may not be possible in denied environments.

Lower-Cost Sensing and Attack Platforms

The US and UK militaries could develop attritable forces that can be manufactured and employed at lower cost, en masse, and at a lower risk level for human operators.

- **Imperative:** Adversaries have developed A2/AD concepts and capabilities that place US and UK forces in certain regions at risk, limiting their operational choices and increasing the probable cost of operations in those regions, at the same time as decreasing their probability of success.
- **Promise:** Lower-cost, more expendable machines would enable commanders to shift operational risk to machines and execute previously unacceptable manoeuvres or more determined defences, all with the reassurance that their own combat losses will mostly consist of machines, not human lives (or irreplaceable machines). Forces might also be able to generate more mass

51. Kathleen Walch, 'How AI is Finding Patterns and Anomalies in Your Data', *Forbes*, 10 May 2020.

than they can today, allowing units to attack simultaneously on many vectors and in greater numbers, overwhelming adversary defences. It is important to note, though, that what is being described here is not a force of machines that can be expended with insouciance. Rather, it is a partial reversal of a mid-to-late 20th-century trend towards ever smaller and more expensive platforms (which partially reflected the need to protect smaller numbers of volunteer service personnel).[52] This stands in contrast to the conditions of the early 20th century, when commanders had far more latitude in expending resources. A Sherman tank, for example, was by no means 'expendable', but the numbers in which it was lost on the Western Front in the Second World War (2,700 were lost by the British alone[53]) made it a much more expendable asset than a modern Challenger 2 or M1A2. Programmes to deliver crewed ground vehicles, to continue the example from the land domain, will not create an endless reserve of cheap machines, but their success might be measured in terms of whether they can generate platforms that are as expendable as early 20th century crewed vehicles.

- **Desired effect:** If attritable forces are created in sufficient numbers, massed machines, when assigned tasks by their human teammates, could overwhelm traditional defences, often at a relatively small cost in human casualties compared with more traditional offensive operations.[54] These changes would increase the number of options available to US and UK commanders, and thus an opponent's operational uncertainty.

Uncrewed Sustainment for Expeditionary Forces in Contested Environments

US and UK forces could use HMC and HMT to improve the resilience of their resupply requirements, increase the survivability of flying and shipping and, if necessary, develop attritable resupply capabilities.

- **Imperative:** In a high-intensity conflict with a near-peer adversary, the US and UK militaries can be expected to suffer attacks against their ability to forward deploy forces and sustain them – attacks designed to paralyse the deployed forces and to prevent additional forces from entering the theatre of operation after a conflict has begun.

52. On this trend, see Caverley, *Democratic Militarism*, pp. 21–40.
53. RLC Alex, 'The Army isn't Serious About Warfighting', *Wavell Room*, 24 August 2022, <https://wavellroom.com/2022/08/24/british-army-conventional-war-fighting/#:~:text=During%20WW2%20the%20British%20Army,rate%20of%200.05%25%20per%20day>, accessed 25 November 2022.
54. Hammes, 'The Future of Warfare'.

- **Promise:** In addition to the potential to create sustainment windows of opportunity by overwhelming traditional defences which might target combat support and sustainment, uncrewed systems could be pre-positioned or moved into theatre to resupply US and UK forces. A combination of uncrewed capabilities used for lift and automated planning could also help resolve one of the major challenges to sustainment – sustaining a dispersed force.[55] Concentrated logistical nodes, although vastly more vulnerable, are currently preferred due to the challenges of planning and delivering logistical support to dispersed capabilities. Automation and AI could substantially reduce this burden by simplifying the process of planning and enabling sustainment to occur without the need for large numbers of crewed platforms.[56] This could simplify tasks such as dispersing aircraft to mitigate the risks that adversary cruise and ballistic missiles pose.
- **Desired effect:** If the US and UK militaries were able to sustain their operations using HMC and HMT in these ways, they could continue fighting at a higher level of intensity for longer, inflicting greater losses and increasing their adversary's uncertainty, thus weakening the adversary's ability to gain military advantage.

Enhanced Operational Deception

Deceiving adversarial forces would reduce US and UK losses and strengthen forces' ability to penetrate adversary spaces.

- **Imperative:** As mentioned in the context of the capabilities discussed above, adversaries are increasingly able to deny the US and UK militaries access to theatres, reducing their ability to mass force or achieve decisive results using conventional means.
- **Promise:** HMC and HMT can (partially) automate computer network attacks against adversary data links and ISR platforms. AI can identify weaknesses in software or security programmes,[57] while HMT can also enable feints in both physical and electromagnetic spaces and set the conditions for maintaining communications in the face of adversary disruption – for example, by more rapidly identifying which parts of the spectrum an opponent is seeking to deny (and thus which parts of the spectrum adversary forces are using). HMC

55. Brian Matthews, 'Autonomous Vehicles: New Technology Revolutionizes Army's Principles of Sustainment', *US Army*, 31 August 2022, <https://www.army.mil/article/259621/autonomous_vehicles_new_technology_revolutionizes_armys_principles_of_sustainment>, accessed 17 April 2023.
56. George Galdorisi, 'The Importance of Unmanned Logistics Support for a Transforming Marine Corps', *CIMSEC*, 1 June 2022, <https://cimsec.org/the-importance-of-unmanned-logistics-support-for-a-transforming-marine-corps/>, accessed 9 March 2023.
57. Bob Violino, 'Artificial Intelligence is Playing a Bigger Role in Cybersecurity, but the Bad Guys May Benefit the Most', *CNBC*, 13 September 2022.

can improve operational planning, including deception planning, particularly against other systems that leverage machines. Strategies for poisoning an opponent's ML algorithms or hiding in plain sight require an understanding of how an opponent's AI draws inferences based on decisions made. Understanding how an opposing AI works (and how it might be overcome) is thus one area where HMC can be applied.[58]

- **Desired effect:** If the US and UK militaries can use HMC and HMT to enhance operational deception in these ways, they should be able to lead adversary forces astray; disrupting or derailing their ongoing operations, and injecting uncertainty about the validity of reports, intelligence analysis and vital systems performance.

Leverage HMC for Predictive Maintenance

Automating a range of maintenance and back-office functions could enable more rapid and efficient operations and free up human capacity for other tasks.

- **Imperative:** High-intensity or long operations, and long and complex supply lines, require efficient and anticipatory maintenance.
- **Promise:** Automation and digitisation have the potential to predict attrition and repairs.
- **Desired effect:** Enable the US and UK militaries to enhance and harden logistics operations.

What Enablers Do the US and UK Militaries Require for the Adoption and Employment of HMC and HMT?

HMC and HMT will not emerge and operate in a vacuum. Their incorporation by the US and UK militaries will heavily depend on critical enablers within the US Department of Defense (DoD) and the UK Ministry of Defence (MoD), broader government institutions, and a diverse external ecosystem. The most important enabling factors are discussed below.

New Operating Concepts

Military personnel collaborating with machines can break problems into their component pieces and instruct machines to optimise, automate and perform

58. Author interview with UK AI subject matter expert, London, 5 January 2023.

tasks at scale, allowing the HMT to make decisions and conduct operations more effectively, more quickly and on a larger scale than humans alone can do.[59] But militaries are unlikely to make this transition without changing their operating concepts to account for the speed and scale machines provide. If militaries attempt to use machines to simply augment or replace human performance, they are likely to secure only a fraction of the possible benefits of HMC and HMT. In addition to not deriving the competitive advantages they might enjoy if they properly employed their tools, commands that do not experience the benefits will not be as incentivised to adopt the technology.

Three considerations should characterise the operating concepts that drive HMC and HMT adoption. The concepts must be linked to a specific military problem and connected to a recognisable model of operation.

Most major innovation cycles begin as a response to a well-delineated challenge. The precision-strike revolution in Western militaries that began with the Second Offset, for example, started as a solution to the challenge of defeating the Soviet second echelon. It then gained much wider currency as the broader implications became apparent. However, the revolution in military affairs did not begin with a broad theory of change; rather, it came about as a solution to a very specific problem.[60] This is true of other innovations, such as the interwar Japanese Navy's adoption of carrier warfare to offset its disadvantages in battleship tonnage.[61] In the case of HMC and HMT, the central orienting challenge should be overcoming layered standoff and enabling both theatre entry and manoeuvre. This is by no means their only potential application, but linking the development of HMC and HMT to a challenge that will be critical to every Western service against peer and near-peer competitors should ensure clear and well-supported lines of effort in developing concepts and capabilities.

New concepts of operations should be linked to recognisable principles for action in order to be readily understood and adopted. Interwar Germany's rapid adoption of armoured warfare, for example, was partially driven by the fact that many of its tenets, such as infiltration and manoeuvre at depth, were already embodied in First World War stormtrooper tactics. Tanks were added into an existing concept of operations (CONOPS) that they substantially changed, but without which their role might not have been understood. In effect, the German army reached the right conclusions about technology because its pre-existing critical task focus and concepts were well suited to doing so. Today, elements of the US and UK joint forces that have particularly well-aligned CONOPS and are task

59. Iansiti and Lakhani, 'Competing in the Age of AI'.
60. Dima Adamsky, *The Culture of Military Innovation: The Impact of Cultural Factors on the Revolution in Military Affairs in Russia, the US, and Israel* (Stanford, CA: Stanford University Press, 2010), Chapter 3.
61. David C Evans and Mark R Peattie, *Kaigun: Strategy, Tactics, and Technology in the Imperial Japanese Navy 1887–1941* (Barnsley: Seaforth Publishing, 2012), p. 243.

focused should be prioritised as accelerators for the adoption of HMC and HMT in the context of achieving theatre entry.

Effective Interfaces

Effective teaming depends on a two-way flow of information and robust cognitive and behavioural models of the agents involved. With the progress of machine intelligence from tools to peers, human–machine interfaces will require increasingly advanced social intelligence in machines to support complex interactions and coordination demands between the agents. Optimising this interface requires machines to build accurate mental models of human teammates in dynamic and ambiguous operational contexts. For humans, integration is contingent on trust and confidence in their machine counterpart's ability to execute goals safely and reliably to achieve advantage over adversaries. To improve the transparency and value of the interface, human operators need to understand the interdependencies and respective capabilities of human and machine agents in the system.

The degree to which human operators require an explanation of the workings behind a machine's output depends on contextual factors like time sensitivity and the level of operator accountability for actions taken. Moreover, the extent to which a machine's working can be simply explained under different contextual conditions should be made a design criterion at early stages of development.[62] It has also been suggested that end users be involved in the early stages of interface development so that they can offer feedback on matters such as the graphic user interface.[63]

Workforce

The US National Security Commission on AI's Interim Report included an AI Workforce Model. Developed in partnership with the Joint AI Center and the Defense Innovation Board, the model outlines workforce requirements for the DoD. While intended to address AI, this model applies equally well to HMC and HMT. It calls for the DoD to develop three archetypes at different skill levels for the technical workforce – AI expert, AI developer and deployment specialist – and four archetypes for the non-technical workforce – end user, tactical leader, strategic leader and support roles.[64] According to the model, adequate support

62. Anna Knack, Richard J Carter and Alexander Babuta, *Human-Machine Teaming in Intelligence Analysis* (London: Turing Institute, 2022), pp. 10–17.
63. *Ibid*.
64. For more on the AI workforce model, see National Security Commission on Artificial Intelligence, 'Interim Report', November 2019, p. 61, <https://www.nscai.gov/wp-content/uploads/2021/01/NSCAI-

for all seven archetypes will produce the technical workforce needed to build and field HMC and HMT, the strategic leaders needed to make policy and resource decisions, the tactical leaders and end users needed to employ HMTs, and the support roles needed to staff the acquisition, legal, and personnel systems. With this talent in place, the US and UK militaries would be much more likely to effectively develop, field and employ HMC and HMT.

In some cases, the expertise needed to train personnel in these roles may already exist within the force. For example, the operators of air defence systems such as Aegis destroyers/cruisers are among the more experienced end users of automated capabilities in the military. They have had to grapple with considerations like setting parameters for a system rather than directly controlling it, interpreting incoming data from a system, cross-referencing it with a commander's judgement, and deciding how much autonomy to allow a system.[65]

In other categories, it may be necessary for militaries to rely on other models to source and retain talent. For example, private contractors might be one avenue through which militaries can reach out to qualified individuals without directly paying salaries that would void the pay/rank relationship. Given the substantial levels of contractorisation that have already occurred in Western militaries, this need not be a great leap.[66] Use of reserve units might be another way of attracting qualified individuals without denying them their full earning potential. Countries such as Israel have succeeded in making postings in specialised units such as Unit 8200 (Israel's SIGINT and cyber unit) sought-after jobs because of the private sector opportunities the unit's alumni enjoy following a limited period of service. Reserve units could build links with the private sector to be similarly effective.

Ethical Guidelines

The deployment of HMTs in increasingly complex and ambiguous environments requires machines to negotiate ethically challenging situations in which decisions have many consequences, including for human safety. Meaningful human control over systems and morally consequential decision-making remains critical, but the appropriate degree of autonomy will vary across missions. Militaries need to not only calibrate the tradeoff between control and autonomy in ethical HMT design, but also to define the parameters for dynamically adjusting this calibration to different situational contexts. Developing ethical models for

Interim-Report-for-Congress_201911.pdf>, accessed 26 April 2023.

65. RUSI Western Way of War Podcast, 'Episode 49: Archer Macy: How Do You Know?', 6 May 2021, <https://rusi.org/podcasts/western-way-of-war/episode-49-archer-macy-how-do-you-know>, accessed 26 April 2023.

66. P W Singer, *Corporate Warriors: The Rise of the Privatized Military Industry* (Ithaca, CA: Cornell University Press, 2007).

systems will be particularly important in situations where machines exercise a high degree of autonomy. Models should account for the moral reasoning of multiple human and non-human agents interacting in an evolving environment.

Structured Spaces for HMC and HMT Experimentation

Experimentation is helpful for the development of both capabilities and new employment techniques/operational concepts. Experimental spaces should replicate realistic environments so that operators and technologists can experiment with and rapidly iterate technology to develop its optimal use across situational contexts. Locations such as the US's Joint Readiness Center, the National Training Center and the Joint Multinational Readiness Center already provide realistic environments.[67] High-fidelity simulations also offer opportunities to quickly iterate experiments, especially in preparation for real-world scenarios. To field new capabilities quickly, the operators and technologists should also be tightly connected to industry and to the acquisition systems of the US and UK militaries. Where possible, collaboration between allies could shorten these experimentation and acquisition cycles and enable further integration between them in the future. But to achieve this, classification differences that have hampered cooperation efforts in other domains would need to be overcome.[68]

Fielded Experimentation

Current processes for upgrading and using legacy systems are too slow to produce rapid adaptations to tactics on the battlefield. Driving innovation into existing weapon systems at the speed of relevance requires a new experimental paradigm, with operators continually testing capabilities in the field to build trust, developing metrics of effectiveness and updating capabilities in real time to make behaviours unpredictable. Fielding high-fidelity simulations of AI-enabled systems at the tactical edge, developing operator-focused analysis tools to evaluate risks and opportunities provided by new HMT tactics, and deploying synthetic data generation to adapt systems using in-situ collected data would enable battlefield

67. US Army, 'U.S. Army JRTC and Fort Polk', <https://home.army.mil/polk/index.php/units-tenants/jrtc-operations-group>, accessed 26 April 2023; US Army, 'The National Training Center and Fort Irwin', <https://home.army.mil/irwin/index.php/about/mission>, accessed 26 April 2023; DoD, '7th Army Training Command', <https://www.7atc.army.mil/JMRC/>, accessed 6 March 2023.
68. Erik Lin-Greenberg, 'Allies and Artificial Intelligence: Obstacles to Operations and Decision-Making', *Texas National Security Review* (Vol. 20, No. 2, 2020), pp. 56–76.

operators to create on-demand tactics and rapidly deploy capabilities in response to a dynamic threat environment.

Acquisition Reform

The US and UK militaries both need to develop more effective ways to work with industry to create capabilities. This entails addressing well-known issues with the acquisition process, programme risk and efficiency approaches to position the military–industrial–academic complex to learn and develop capabilities in real time as part of an action–reaction–counteraction cycle. Experimental spaces would also help to improve collaboration between military users and civilian-led technologists early in the development phase to identify necessary capabilities and improve the path to production and fielding, particularly at scale. The current defence infrastructure is not set up for the appropriate scaling and will need to be adapted to move technologies beyond the experimentation phase.

Key adaptations must include incentives that make it appealing for a company to invest in technology at technology readiness level (TRL) 1. Target margins for companies specialising in AI-enabled military solutions may be up to 25% of costs – well more than the margins that defence contracts typically deliver.[69] This disparity of expectation will be compounded by the tendency of defence departments to insist on intellectual property (IP) ownership. Solutions might include exploring the role of institutions such as the British Business Bank in delivering long-term R&D funding to technology at lower TRL levels. Payments could also be made on a 'stages of intent' basis, thus reducing the risk to companies depending on an uncertain contract award. Finally, direct state ownership stakes in critical companies might be considered.[70]

69. Sidharth Kaushal, John Louth and Andrew Young, 'The Exoskeleton Force: The Royal Navy in the Indo-Pacific Tilt', *RUSI Occasional Papers* (November 2022), p. 18.
70. *Ibid*.

IV. Guiding Principles for the Implementation of HMC and HMT

Translating the vision articulated above into tangible outcomes will depend on several factors, including political support for efforts to leverage autonomy, reforms to processes surrounding acquisition and the institutionalisation of fielded experimentation within a country's armed services. The challenge is multiscale and will require many stakeholders' simultaneous engagement. This chapter highlights the ways in which different stakeholders within the policy process, and at various levels, can drive change.

The Political and Strategic Drivers of HMC and HMT Adoption

Political and senior civilian and military leaders must provide a clear vision and direction for implementation to lead the digital transformation. In democracies, policymakers often provide strategic direction to (and oversight of) militaries without engaging with the details of military change, which tends to be viewed as the domain of the specialist.[71] While this is understandable, policymakers taking an active interest in force transformation is often a prerequisite for successful adaptation and evolution.[72] Without suggesting that political leaders attempt to direct the tactical details of how militaries leverage HMC and HMT, this chapter outlines ways in which they can galvanise the process of change.

Define Vision

Driving HMC and HMT as part of the digital age's transformation of the art and science of defence and security requires a well-defined vision. HMC and HMT must be cast as part of a 'grand design', not left to random experimentation at

71. Samuel P Huntington, *The Soldier and the State: The Theory and Politics of Civil–Military Relations*, (London: Belknap Press, 1957).
72. Barry R Posen, *The Sources of Military Doctrine: France, Britain, and Germany Between the World Wars* (Ithaca, NY: Cornell University Press, 1984).

the fringes. Senior leaders in the defence establishment must articulate a vision of warfighting at the scale needed to win a great power war, then communicate it and resource it aggressively to spur services to implement HMC and HMT as an integral part of the solution to the operational challenges facing the US, the UK and their allies. Leadership must articulate the pressing threat, and how HMC and HMT can be employed to address it. The poor framing of operational challenges can cause bureaucratic elements to withdraw the support that is critical to overcoming the 'valley of death' in implementation. Leaders could find themselves having to justify cuts to existing capabilities to enable change, which requires political capital and bureaucratic support to achieve in the face of organisational inertia.[73]

Realising a well-defined organisational vision can also require a certain ruthlessness. Consider, for example, the controversies that accompanied the early 20th century dreadnought revolution, which was enabled by cuts to the Royal Navy's fleet of pre-dreadnought battleships, many of which were scrapped.[74] Notably, the methods that Admiral Fisher used to defend and sustain change, including relatively centralised decision-making using small groups and a willingness to weather external criticism, might be at odds with contemporary managerial standards. This dynamic is mirrored in the careers of other successful reformers, such as Admiral Rickover.[75]

Integration with Other Strategies

The development and employment of HMC and HMT must be integrated components of a broad strategy, rather than being left to experimentation in small, disparate programmes. As the Second Offset illustrates, holding service-level programmes to a centrally defined strategy can be the best way to both deliver the value of a coherent central vision and give services the latitude to propose their own programmes. However, it would be a mistake to assume that strong personalities like former US Secretary of Defense Harold Brown will always be at the helm to drive this kind of process – relying on remarkable individuals leaves too much to chance.[76] There should be an institutional basis for ensuring alignment with an overall vision. Organisations such as the UK's

73. Consider, for example, proposals to implement a mixed crewed–uncrewed structure within the US Navy. See Bryan Clark et al., *Implementing Decision-Centric Warfare: Elevating Command and Control to Gain an Optionality Advantage* (Washington, DC: Hudson Institute, 2021).
74. Arthur J Marder, 'Admiral Sir John Fisher: A Reappraisal', US Naval Institute, March 1942, <https://www.usni.org/magazines/proceedings/1942/march/admiral-sir-john-fisher-reappraisal>, accessed 17 February 2023.
75. Peter Hennessy and James Jinks, *The Silent Deep: The Royal Navy Submarine Service Since 1945* (London: Penguin, 2015), pp. 150–60.
76. Edward Keefer and Erin Mahan, *Harold Brown: Offsetting the Soviet Military Challenge, 1977–1981* (Washington, DC: Office of the Secretary, Historical Office, 2017).

Strategic Command, which currently plays a role as a technical integrator, could take on the function of ensuring overall coherence as an institutional imperative. Organisations that play this role can also share innovation across services and combine service-level initiatives where appropriate. One might consider, as a commercial analogue, the role that organisations like Japan's MITI have played in guiding collaboration between companies.[77]

Articulate Priority Capability Categories, with an Initial Emphasis on Enhancing Existing Force Design

Any implementation plan should articulate a list of priority capability categories for HMC and HMT, such as the provision of low-cost sensing and the enablement of dispersion through automated planning. Buy-in will depend either on the cooperation of the owners of legacy assets or on their being effectively sidelined. While figures such as Admiral Fisher managed to sideline their opponents, this may not always be viable. The highest levels of buy-in are attained when an innovation appears to enhance, rather than to replace, existing kit. For example, aircraft carriers were initially 'sold' to battleship admirals using the argument that aircraft could act as spotters for battleships, while vertical lift achieved buy-in because it was seen as enabling existing concepts of cavalry manoeuvre.[78] Consider these adaptations to secure buy-in as examples of 'single loop learning', in which an organisation's existing way of doing things is made more efficient.[79]

Initial buy-in can set the conditions for more revolutionary long-term change by, among other things, opening promotion avenues for reform-minded officers.[80] In HMC and HMT command and control, ISR and counter-ISR are areas where machines can augment, rather than supplant, existing capability. It is these areas that should be prioritised first, with the use of lethal and expendable platforms (a more politically and organisationally challenging area) initially deferred to a second phase of exploitation.

77. Qingming Song, 'Political Economy Analysis of Significant Roles of MITI in Japan's Industrial Policies During Japan's Post-War Economic Miracle Period', *Proceedings of the 2022 International Conference on Economics, Smart Finance and Contemporary Trade* (ESFCT 2022).
78. Stephen Peter Rosen, *Winning the Next War: Innovation and the Modern Military* (Cornell, CA: Cornell University Press, 1991), pp. 75–79, 80–86.
79. Frank G Hoffman, *Mars Adapting: Military Change During War* (Annapolis, MD: Naval Institute Press, 2021) pp. 18–50.
80. Rosen, *Winning the Next War*, pp. 70–90.

Questioning Assumptions

Assumptions made about the development of capabilities need to be carefully interrogated, including the continued reliability of internet connectivity for military and civilian capabilities, the resilience of uncrewed systems, opportunities to collect or generate data required for ML, and the expertise required of humans and machines to perform tasks linked to an operational concept.

Communication

One major barrier to innovation and change is the fear of being perceived to be wasting public money. Bureaucracies are often set up to avoid waste – a potentially virtuous function – but in doing so, they can impede the levels of experimentation needed to drive change.[81] However, politicians and the public need not be an impediment to expenditure on high-risk, high-reward ventures – indeed, in important cases like the space race or the building of the dreadnought, they drove the process. Winning the support of politicians and the public can undermine a major rationale for opposition to change – the argument that the levels of experimentation needed to support change will be deemed financially frivolous. For example, we might think of the 1957 exercise in which the USS *Nautilus*, then the world's only nuclear-powered submarine (SSN), 'sank' a great deal of the Royal Navy. The intended audience for the exercise was not the Navy (which already understood the value of SSNs), but the secretary of state for defence, Duncan Sandys, who had been invited to attend and who subsequently offered wider political support for a British SSN in the face of Treasury opposition.[82]

The development and adoption of HMC and HMT require the involvement of stakeholders outside of the DoD and the MoD. Defence leaders must engage, and at times inform, their governments and the public. Building coalitions of support beyond the services and defence establishment is one way in which the initial momentum of programmes can be sustained. This was well known to successful reformers like Hyman Rickover, who was careful to cultivate relationships with both Congress and the press.[83]

Engagement with Legislators

Amid many competing priorities, the DoD and the MoD must convey the urgency of HMC and HMT implementation to legislators in terms of the potential costs

81. Participant at Special Competitive Studies Project and RUSI HMT workshop, London, 2 February 2023.
82. Hennessy and Jinks, *Silent Deep*, p. 170.
83. Francis Duncan, *Rickover: The Struggle for Excellence* (Annapolis, MD: Naval Institute Press, 2001).

of failure. The war in Ukraine has showcased the importance of HMC and HMT by presenting a concrete and easily comprehended set of operational challenges that make a clear case for their implementation.

Politicians and the wider public should also be engaged in a wider strategy of re-industrialisation. Commentators have discussed how, in different areas, some of the enabling technologies that can drive rapid production (such as additive manufacturing and automated production lines) can drive the partial reshoring of manufacturing capacity.[84] If this is the case, the production of expendable capabilities, which could require less specialised knowledge than manufacturing legacy assets, could be tied to wider national industrial strategies and so reinvigorate economically flagging areas in the UK and the US. Legislative buy-in, meanwhile, could give HMC and HMT the political protection that, for example, shipbuilding enjoys in both the UK and the US. To achieve this, however, procurement standards for expendable capability will need to be more permissive than those for crewed assets – enabling investment in generating these capabilities to be viewed as part of a virtuous cycle with spillovers into the civilian economy.

Public Engagement

Implementing new and advanced technologies is not simply an issue of technology, but also involves policy and legislative direction. Successful policy, especially in areas that require organisational change or significant private sector engagement, often requires public engagement. The DoD and the MoD need to improve how they engage with the public – especially when technologies are being driven by the commercial sector – and help it understand the imperative of rapidly developing and adopting HMC and HMT capabilities. This includes prioritising accessibility over technical details when drafting documents for public distribution, as well as highlighting areas where HMC and HMT have previously been operationalised and been of benefit. ‘Easy wins’ in terms of communication can be sought in descriptions of technologies that help shield troops from harm, such as bomb disposal robots.

84. Rana Foroohar, *Homecoming: The Path to Prosperity in a Post-Global World* (New York, NY: Random House, 2021); Hammes, ‘Technological Change and the Fourth Industrial Revolution’, pp. 37–72.

Understanding Where to Implement Incremental Adaptation and Where to Push for Transformational Change

Incremental change is necessary when achieving progress relies on gaining the buy-in of services and industry while still maintaining readiness and overall deterrence. Winning in future conflicts, however, requires transformation, and managed transition may be insufficient to encourage the DoD and MoD to drop enough legacy systems for transformation to take place. The DoD and MoD need a plan for transitioning from yesterday's icons in favour of dedicating programme resources for the short to long term to build a process, not hold an event.

This means pursuing implementation on a two-track process: (a) incremental change, such as by identifying existing platforms or munitions to improve during development and combat; and (b) immediate transformational change, which might involve more bruising organisational change. Success stories can be created, and thus evidence of effectiveness communicated, through testing and modelling/wargaming with inbuilt HMT and HMC capabilities.

The pace at which change needs to occur may not be even across the domains or levels of warfare. The change strategy opted for could, then, be contextually determined. In some cases, direct (and unpopular) cuts by top leadership to existing force structure to fund new a capability may be necessary – like those imposed on the Royal Navy during the dreadnought revolution. Such an approach tends to benefit from more top-down leadership. In other cases, where the pace of change is less breakneck and the truly revolutionary implications of new technology are more unclear, incrementalism may be called for. An example is the carrier revolution, in which battleship admirals were reassured about their position in the emerging force structure. This approach hedged against risks because the implications of carrier warfare were not clear and only emerged 20 years after the first tests of aircraft at sea.[85]

All this implies that a categorisation of areas that require incremental/transformational change should precede decisions on both the approach taken to specific programmes and the choices regarding programme managers.

85. Kyle Mizokami, 'These 1920s Experiments Ended the Age of the Battleship', *National Interest*, 17 November 2021.

Bureaucratic and Organisational Change

Militaries will adopt new technologies or capabilities at uneven rates across their organisations, causing the tempo and scale of operations to change at different rates. These boundaries of adoption can create friction and limit capabilities. To overcome them, the DoD and MoD need to focus on driving behavioural, not cultural, change, because behaviour is more instrumental and controllable, and will gradually feed cultural change. As an example, rather than attempting to create a risk-tolerant culture, the DoD and MoD should establish processes that force or strongly encourage some programmes to fail without ending a programme manager's career, such as portfolio management. A process of adaptation will need to take place, aided by the development of new and evolved organisations that embrace shock, surprise and new forms of organising.

This section will describe some of the priorities on which such a process should be focused to deliver a positive feedback loop of self-reinforcing change.

Manage Internal Competition

Militaries will need to manage budgetary competition between the services, as well as the tension between those focused on the combatant commands' immediate high-readiness capabilities and those looking to generate capability over the medium to long term. Further tensions may result from the way that HMC and HMT blend parochial service roles.

There are two potential approaches to managing competition for a common good. First, control can be centralised in a service-level organisation – as the US has done for space-based C4ISR in the Space Force, and China has for ISR more broadly in the Strategic Support Force.[86] The demand signal from individual services can be mediated by a body that must be appropriately empowered (authority, capacity and resources) so that it is not junior, or beholden to any service, such as the Third Offset's Advanced Capabilities Development Panel, or the National Security Commission on AI's recommendation to establish a tri-chair panel. Second, services can be allowed to make budgetary decisions, with the role of the strategic integrator being to prune ideas inconsistent with the offset vision – as was the case in the Harold Brown years in the US DoD, where the offers of individual services were assessed based on their congruence

86. Elsa B Kania and John Costello, 'Seizing the Commanding Heights: The PLA Strategic Support Force in Chinese Military Power', *Journal of Strategic Studies* (Vol. 44, No. 5, 2020), pp. 1–47.

with the vision of the Second Offset.[87] Authority remains a critical success factor if the integrator is to shape the design of the force from the start (rather than merely integrate the forces it is given).

Interservice competition can, if properly managed, have virtuous effects in terms of services being compelled to ensure their approaches are in fact competitive and expedite the evolutionary process. Here, we might consider the example of how aviation benefited from competition between multiple companies in its early days. Alternatively, services can be given the freedom to expend resources, so long as their expenditure can demonstrate coherence with a precise vision. This was the case in the era of the Second Offset.

The degree to which internal competition is desirable is proportionate to the clarity of the underlying vision. If a vision gives the services clear joint goals, giving them the latitude to make resource decisions may make sense. However, if a vision is not sufficiently defined – and thus open to being interpreted by services in ways that justify their desired programmes – a central arbiter who can identify obvious parochialism may be necessary. An approach where the standardisation of certain elements is performed centrally certainly has historical precedent – consider, for example, how the US Navy's NIFC-CA was predicated on inserting standardisation requirements into pillar programmes.[88]

Clarify and Raise the Risk Threshold

The bureaucratic risk threshold for using new technologies is often unknown, and overall risk tolerance needs to increase, especially for middle management, if technology is to be adopted at scale within relevant timeframes. While leaders are taught at junior levels to nurture innovation and identify acceptable failure, they are not taught how to continue doing so once they become middle managers, where the risk environment is different. The question, then, is how to counter the conservative instincts of middle managers, who often see themselves as the means by which organisational risk is mitigated.

One way of altering behaviour is to change the cues that drive it, rather than altering incentive structures. Most individuals are driven by a degree of inertia which can be manipulated – for example, people are much more likely to benefit from a social programme if it has a voluntary 'opt out' mechanism rather than operating on an 'opt in' basis.[89] In this model, reporting requirements for the

87. Keefer and Mahan, *Harold Brown*.
88. Nicholas A O'Donoughue et al., *Distributed Kill Chains: Drawing Insights for Mosaic Warfare from the Immune System and from the Navy* (Santa Monica, CA: RAND, 2021).
89. Richard Thaler and Cass Sunstein, *Nudge: Improving Decisions About Health, Wealth and Happiness* (New York, NY: Penguin, 2009).

rejection of a given proposal or the slow pace of a programme might be made more onerous, for example. Social cues, such as beliefs about the wider organisation, can also drive emulation – suggesting that highlighting the stories of high performers can drive wider change.[90] People tend to be motivated by the actions of individuals within their social locus. Valorising examples from the private sector is thus unlikely to motivate a state employee, while publicising examples of change being driven within the military may have a greater effect. Finally, rewards and punishments for the responsible owners of programmes might be reframed to incentivise justifiable risk, rather than being predominantly based on outcomes.

Create an Infrastructure that Enables Risk-Taking

The DoD and the MoD can incentivise the use of structured spaces for HMC and HMT experimentation (discussed above in the section on 'enablers') as dedicated spaces for trialling and prototyping high-risk capabilities. Through proper rewards, these spaces could lead to an inventory of innovative and proven operational concepts and technologies, developed during peacetime, which could be rapidly deployed off the shelf in response to the next crisis. It is unlikely to be possible to innovate if, as is currently the case, flying a UAV in a testing ground like Salisbury Plain requires an elaborate permissions process.

In addition to providing experimental spaces, the DoD and MoD must articulate a clear risk threshold for technology implementation: such thresholds are often unknown, which stifles risk-taking. The DoD and MoD can also set a predetermined failure rate for a defined set of programmes to increase risk tolerance, and should be prepared to reapportion funds based on the expectation of failure. In response to failure, they must be prepared to reward people for taking reasonable risk, even when their programmes have proven to be unsuccessful. The DoD and MoD can also exploit lessons learned from partially successful or even failed experiments and leverage subcomponent technologies that emerge from projects.

Define Impactful Metrics

It is often the case that senior leaders have a vision for an outcome but lack an accountability system to track progress and act as a forcing function to drive HMC and HMT implementation throughout the services. The DoD and MoD must build an ecosystem or accountability structure, with reportable and context-appropriate metrics, for the adoption of HMC and HMT capabilities and their

90. Aaron H Anglin, 'Role Theory Perspectives: Past, Present, and Future Applications of Role Theories in Management Research', *Journal of Management* (Vol. 48, No. 6, 2022), pp. 564–78.

impact. Given the diversity of tasks and contexts in which HMC and HMT can be applied, and where their integration is tracked, creating a variety of metrics that capture the context of specific applications is important. Because metrics can be interpreted in different ways, the DoD and MoD must clearly define metrics such that they lead to shared evaluation of performance by all parts of the organisation. These metrics must not only be measurable but also meaningful and observable in impact, not simply in outcome – which may not be relevant to the goal of transformation. Abstracted metrics could include consistency with offset priorities, military effectiveness, affordability, interoperability, adaptability, coherence, exportability and ecosystem capability. Another potential metric might be the degree to which a given capability relies on commercial off-the-shelf technology, although this might not be applicable in all cases.

Development

The DoD and MoD must consider how technology changes over time and how to best upgrade and use legacy systems without limiting their ability to adapt. This entails identifying specific platforms that could be improved, and determining the expertise needed to meet mission requirements effectively. Building capability to perceive and leverage emerging opportunities across the force may represent readiness and advantage over time. Some of the factors involved are listed below.

- **Start with design.** It will be extremely difficult, if not impossible, to adopt new capabilities by using today's force structure. Instead of starting with force structure and then moving to design, it is best to start with an operational need and use that to inform force structure while pursuing new capabilities. The implications of this approach span doctrine, organisation, training, materiel, leadership and education, personnel and facilities with cost awareness. Militaries should also design interfaces for ease of human use and adaptability, not just for end function.
- **Develop iterative design and experimentation processes.** The DoD and MoD must develop an iterative design and experimentation process that enables rapid and continual adoption, deployment and adaptation of HMC and HMT capabilities at scale. Design and experimentation, foremost, must focus on goals and constraints, rather than on specific techniques that would work in certain contexts and fail in others, and account for the differential effect of components as they come onboard. Doing so will help the DoD and MoD integrate new technologies over time, and upgrade and maximise the value of legacy systems.
- **Build data infrastructure.** Leveraging the full potential of HMT requires an integrated digital data and infrastructure stack. Identifying and using surrogate data sources would also help to inform and generate data.

- **Develop continuous integration and continuous delivery (CI/CD).** Adaptation at the rate needed for effective performance in combat requires a combination of field experimentation, scenario-informed testing and CI/CD. CI/CD is particularly difficult for the types of operations militaries must execute. A tiered approach by which the DoD and MoD create the ability to adapt, then increase such adaptation over time, towards a combination of fielded development and CI/CD, would help improve capabilities and modernise most effectively. This might be much more viable for single-purpose platforms than for crewed multi-purpose ones. As such, should the UK and the US achieve a data architecture sufficiently open and modular in crewed platforms, the capabilities these platforms are teamed with can be improved at pace. This has been achieved, to an extent, by services such as the Royal Danish Navy, which has made modularity a core design principle. However, it does mean that where the demands of modularity clash with platform performance in the immediate term, the former objective is to be given priority.
- **Achieve scale.** Western militaries' capabilities have been limited by the inability to field systems at scale. It is deceptively easy to launch AI pilot programmes with impressive results, but fiendishly difficult to deliver scaled final results. It should be noted, however, that quality defeats quantity in certain contexts, and some HMC and HMT capabilities may not require scale to be significant. Drones in Ukraine, for example, experienced a high attrition rate even in the absence of sophisticated counter-drone and counter-autonomy systems.
- **Ensure interoperability and interchangeability.** The DoD and MoD must design HMC and HMT systems with architecture that facilitates interoperability, interchangeability and fusion between systems, platforms and programmes across the services (and which are compatible with allies' systems). This will require decision-making at the beginning of the procurement process and communication to industry about which partners will be part of the process. In the past, senior leadership-driven programmes such as the UK's Defence Innovation Initiative and the Strategic Capabilities Office proved to be successful models for breaking down firewalls and fusing capabilities across the services to deliver new and improved capabilities. Senior DoD and MoD leadership must similarly intervene to establish an office (or other institutional mechanisms) that can fuse capabilities and special access programmes from across the services.
- Differences in classification levels impose another challenge for interoperability across allies and partners. The DoD and MoD must experiment with eliminating or suspending regulations that impede interoperability/interchangeability, engage in NATO standardisation agreements early, and integrate HMC and HMT into the NATO force model and 2023 family of plans to increase the probability of relevance and implementation.

- **Leverage modelling and simulations.** Modelling and simulations can serve as powerful tools for rapidly developing and deploying HMC and HMT tactics and capabilities that empower the warfighter. The DoD and MoD must explore ways to: use modelling in large, complex simulations of the operating environment; field high-fidelity simulations of AI-enabled systems at the tactical edge; and use synthetic image generation to adapt systems using in-situ collected data to enable battlefield operators to create on-demand tactics and rapidly deploy HMC and HMT capabilities. In addition, the models need to incorporate as many details about the systems in question as possible. Models that make assumptions about systems, such as their inherent vulnerabilities, could have a counterproductive effect if they are then used to inform policy and planning.
- **Emphasise the user interface.** The DoD and MoD must also emphasise the ease of human use and adaptability in the design of interfaces, not just the end function of these systems. This includes the design of analysis tools to be operator-focused so that it is possible to continually evaluate risks and successes of new HMC and HMT tactics in the field. Iterative field experiments that gradually reduce errors and improve understanding of the boundary conditions of technologies can also help to generate trust and accelerate HMC and HMT adoption.
- **Pursue industrial policy.** Industrial policy matters as much as military concept: inventory and production capacity must match the rate and endurance of use. The DoD and MoD need to improve their ability to integrate systems with wider government policy. Nesting acquisition within industrial policy, such as ‘friendshoring’, is one way to circumvent budgetary challenges. Competitors are able to provide insurance against risk to private sector actors via industrial policies that include subsidies. While direct subsidisation is likely to be politically difficult in the UK and the US, incentives such as tax breaks for smaller companies may be more acceptable. There could also be a substantial role for larger defence primes to act as acquisition hubs and as portfolio managers for smaller firms (given that the latter are unlikely to generate economies of scale quickly).
- **Experimentation.** The systems deployed today are not necessarily the same systems that are used to fight tomorrow, and experimentation is key to identifying the most impactful capabilities and outputs to win the next conflict. Given the speed of innovation and adaptation on the battlefield, new experimental paradigms are needed to iterate quickly, update tactics and generate new tools at the speed of relevance. Experiments should focus on goals and constraints, rather than on specific techniques (which will work in certain contexts and fail in others), and account for the differential effect of components as they come on board. Processes and regulations should also be the subject of experimentation.

- **Generate options through modelling.** Generative models provide another powerful set of tools for developing 'course of action' options. Experimentation should first involve modelling in large, complex simulations of the operating environment with physical, human, cognitive and resources layers, or a single synthetic environment.
- **Create on-demand tactics.** Fielding high-fidelity simulations of AI-enabled systems at the tactical edge and using in-situ collected data would enable battlefield operators to rapidly deploy capabilities. Developing operator-focused analysis tools to evaluate risks and successes of new HMT tactics and fielding experiments to reduce errors and understand the boundary conditions of a technology are critical to generating trust in systems and their outputs.

Private Sector Partnership

Today's talent will focus on their current problems more than transformative new capabilities and their potential. Militaries need to consider how technology changes organisation and processes – including the human component, which needs more attention in both the US and the UK.

Several steps can be taken to generate synergies between the public sector and private industry. These include:

- **Integrating civilian expertise.** Competition for talent is extremely fierce. The DoD and MoD need the right talent across their organisations to make effective – not just deeply technical – decisions, but there is no flood of talent appearing, and Defence is not positioned to recruit the best talent. The DoD and MoD need to develop more effective mechanisms to integrate out-of-government expertise into government decision-making. This could be achieved with individual personnel by implementing secondments and rotations between government roles and private industry, as well as processes of co-creation, allowing for an exchange between technical experts and domain operators, with benefits accumulating over time to both sides.

  Another mechanism to draw on civilian expertise might be the better leveraging of reserves. If reserve forces were treated as a pool of talent that serves in the military on a part-time basis, rather than purely as a means of replacing combat mass, they could be a valuable national asset. This model has been demonstrated to be effective in countries such as Israel. There is already some experience with this in the UK, which established the Joint Cyber Reserve Force. Such an approach requires the careful management of demands on an individual's time, as many of the personnel whose skills are being sought will have considerable professional obligations.

Alternatively, the private sector might offer avenues. Private military companies (PMCs), for example, can potentially pay skilled individuals far more than militaries can, and can in principle act as incubators for adaptation and change if supported by state investment. Of course, this raises broader issues regarding regulating their activities in third-party states. Nonetheless, the effectiveness of PMCs such as Military Professional Resources Inc in achieving tasks that have eluded many Western militaries (such as completing successful advise-and-assist missions with a light footprint) suggests that they offer an avenue to tap and retain talent.

- **Fuel industry–government experimentation.** The military relies on civilian sector machines, datasets and infrastructure. An experimental centre or command environment for collaboration between functional and technical expertise would help to not only bridge the gap between military users and civilian-led technologists but also to better leverage private sector data. Partnered experimentation and training between armed forces and industry should be fuelled by government cash, and not just by industrial goodwill. Initiatives of this kind should also highlight the imperative of positioning the military–industrial–academic complex to learn in real time, within conflicts, as part of the action–reaction–counteraction cycle.
- **Reform the acquisition process.** More effective relationships between government and technology companies will also be key to overcoming well-known issues with the acquisition process. The DoD and the MoD should establish open-standard acquisition with industry to create rapid spiral development, not leisurely episodic fleet changes. This involves making space for original equipment manufacturers and start-ups (without being seduced by either). It must be recognised that the time taken to bring a new technology to the higher TRLs means that it is simply not viable for smaller entities to compete in the defence sphere. One way this could be circumvented is if large defence primes act as portfolio managers – purchasing smaller entities at a pace which means that their investments can pay off before the technology has matured to MoD/DoD standards. Incentive structures for defence primes will need to be adjusted to achieve this. While some tools, such as tax cuts, might be too politically fractious, other policy instruments, such as direct state investment in research and development, which already occurs to a significant extent in the medical sector, might be an alternative.

Conclusions

This policy guide demonstrates the extent to which HMC and HMT are essential for Western militaries. A combination of capable individuals – particularly at junior levels – and both AI and autonomy enables concepts of manoeuvre that are challenging for more rigid and hierarchical command structures. Such concepts could prove to be the bane of technologically sophisticated but organisationally rigid opponents. HMC and HMT also promise to deliver the redundancy that Western force structures have lacked since the end of the Cold War, but require in order to succeed in future conflicts.

The integration of HMC and HMT into force design will, however, be predicated on several structural and cultural changes within defence. In particular, altering procurement priorities to emphasise expendable capabilities and improvements in software (rather than in hardware) will require levels of risk tolerance that challenge deeply ingrained organisational qualities and processes. In addition, the cultivation of human capital will remain an enduring concern that will be as important as procurement.

The approaches that militaries and defence bureaucracies take will be contextual. There is no 'one size fits all' solution. As illustrated in this policy guide, the leadership styles and levels of risk tolerance needed will depend on factors such as the immediacy with which a given capability must be fielded, the opportunity costs of delivering it, and institutional flexibility. In some cases, the benefits of better resourcing existing capabilities may outweigh those gained from using HMC and HMT. In other contexts, the imperative to use HMC and HMT will be overriding.

The history of conflict is punctuated with moments of disruptive change that fundamentally alter the character of warfare. The confluence of unprecedented volumes of data made available and usable by AI, the growing ubiquity of automation, and the emergence of new modes of producing physical capabilities could mean that we are on the cusp of such a moment. Those states and organisations that have benefited most from periods of change were institutionally capable of comprehending the ways in which they could leverage new capabilities and integrate them at scale. Since transformation requires the state as a whole to play a role, the requirements to achieve it must be understood beyond the uniformed military. This policy guide serves as a framework that outlines both the opportunities provided by HMC and HMT and the approaches that can facilitate adoption. Though it makes no specific claims regarding large programmatic decisions, it strives to offer a basis on which such decisions might be made in the future.

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