Extending the intellectual edge with artificial intelligence

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We will never again think or work as slowly as today.[1]

This statement is representative of the pace of change in the world at present. It is no exaggeration; indeed, it may underestimate the impact the acceleration of change is having on the strategic environment.

The world now sits at the precipice of an era in which humans and machines will be able to collaborate in a much more symbiotic way. The rapidly evolving capabilities of artificial intelligence (AI) will enable better and faster decision-making by military leaders. The human councils of previous times will likely be replaced with AI decision-support tools. In as little as a decade, it may not be possible to generate advantage at most levels of the military, or in many other human endeavours, without assistance from some form of AI. It is therefore necessary for military institutions to anticipate what this means for their organisations, their ideas and the development of their leaders, lest they join the long line of military forces whose failure to anticipate change has seen them suffer catastrophe.

In his book on military innovation, Dima Adamsky describes how a military institution needs 'to figure out the tools of war (the hardware) and anticipate their application (the software). The task with regard to software will be much more demanding.'[2] This domain of 'military software'—the formulation of concepts, innovative structures and processes; and, the intellectual preparation of military leaders for the task of 'figuring out' the tools of war at their disposal—is where wars can be won and lost before a shot is fired. But insufficient attention in this area can result in a capa-

1 Statement from a representative of a 'big tech' company during the author's visit to San Francisco, Silicon Valley and Seattle in June 2019.

2 Adamsky, D., *The Culture of Military Innovation: The Impact of Cultural Factors on the Revolution in Military Affairs in Russia*, the US and Israel, Stanford Security Studies, 2010, p. 142.

bility gap in military organisations, which may be difficult to perceive by those inside and outside of those institutions.

This gap (which I have described elsewhere as a *military software gap*[3]) can result in a failure of imagination, a failure of anticipation, and a failure of adaptation.[4] It is a gap that has caused military failure from antiquity through to modern times. Therefore, this article will examine how military forces, as well as the broader national security community, might apply knowledge of advanced technologies to build an evolved *intellectual edge* and thereby prevent the formation of this software gap. I will argue this by first examining the rapid changes in technology, demography and geopolitics that are affecting our strategic environment. This will be followed by a review of how nations generate strategic advantage, and why an intellectual edge must be a strategic focal area. Finally, the article will assess how the application of AI may assist institutions to build an intellectual edge for leaders in this evolving strategic environment. This is an important question given the principle issue driving change in our current milieu: speed.

The era of accelerations

> We're entering an age of acceleration.[5]

Changes in the global environment—in geopolitics, demographics and technology—are occurring against the backdrop of what Klaus Schwab has described as the Fourth Industrial Revolution. This revolution is underpinned by connectivity, biotechnology and silicon-based technologies that include AI.[6]

But these developments possess many historical precedents. The first Industrial Revolution led to a proliferation of technology and manufacturing on a scale not witnessed before.[7] It was followed by another industrial revolution, from the late 1800s to the early 1900s, which resulted in motor cars, airplanes, wireless communica-

3 Ryan, M., 'An Australian Intellectual Edge for Conflict and Competition in the 21st Century', *Centre of Gravity Paper No. 48*, Coral Bell School, Australian National University, March 2019.

4 These themes are examined in a range of sources. Among the best are: Cohen, E., and Gooch., J., *Military Misfortunes: The Anatomy of Failure in War*, Vintage Books, New York, 1990; Murray, W., and Millet, A., (Eds), Military Innovation in the Interwar Period, Cambridge University Press, 1998; See Rosen, S., Winning the Next War: Innovation and the Modern Military, Cornell University Press, 1994; and, Biddle, S., Military Power: Explaining Victory and Defeat in Modern Battle, Princeton University Press, 2006.

5 This term was first used by Kurzweil and Meyer in an article titled 'Understanding the Accelerating Rate of Change'. Kurzweil, R., and Meyer, C., 'Understanding the Accelerating Rate of Change', Perspectives on Business Innovation, 1 May 2003. Source: https://www.kurzweilai.net/understanding-the-accelerating-rate-of-change

6 Schwab, K., *The Fourth Industrial Revolution*, Crown Business, New York, 2016, p. 91.

7 In the decade prior to 1760, Britain exported 4.7 million pounds worth of textiles and 424 thousand pounds worth of steel and iron. In the decade to 1830, it exported 37 million pounds worth of textiles and 2 million pounds worth of steel and iron. Mathias, P., *The First Industrial Nation: An Economic History of Britain*, Methuen and Co., London, 1969, p. 466.

tions, assembly lines and widespread electrification. Some have characterised this second revolution as the greatest technical discontinuity in history.[8] Finally, in the last three decades of the twentieth century we have witnessed the birth of space travel and the explosion of cheap computing and connectivity, this has been described as the Information Revolution.

What distinguishes the current era, the emerging 'Fourth Industrial Revolution', from its predecessors is the pace of change. Max Boot has written that 'innovation has been speeding up. It took over 200 years for the gunpowder revolutions to come to fruition, 150 years for the first Industrial Revolution, 40 years for the second Industrial Revolution and 30 years for the Information Revolution. Keeping up with the pace of change is getting harder and the risks of getting left behind are rising'.[9] This acceleration is also a theme in the 2017 US National Intelligence Council report on global trends,[10] which notes that 'artificial intelligence and robotics have the potential to increase the pace of technological change beyond any past experience, and… may be outpacing the ability of economies, societies, and individuals to adapt'.[11]

The pace of change in technology is well examined in a range of publications. As one author recently noted, 'transformative technology is as old as the sundial'.[12] There are many examples that illustrate this point but one in particular stands out: the Apple iPhone. The iPhone 6S, released in 2015, could process information about 120 million times faster than the mainframe computer that guided Apollo 11 astronauts to the Moon. In 2017, it was superseded by the iPhoneX which had two to three time times the speed of the iPhone 6S; in just two years the increase in computing power had doubled that of the previous 46 years.[13]

The increasing pace of change is not just a technological phenomenon; it is a demographic and societal one. Rapid change is occurring in many other areas, such as urbanisation. The movement of people towards cities has accelerated in the past 40 years, particularly in less-developed regions. For instance, in 1960 a third of the world's population lived in urban areas but by 1999 that proportion had increased to

8 Vaclac Smil uses this phrase in this examination of the era that covers the 2nd Industrial revolution. See Smil, V., *Creating the Twentieth Century: Technical Innovations of 1867-1914 and Their Lasting Impact*, Oxford University Press, New York, 2005, p. 4.

9 Boot, M., *War Made New: Technology, Warfare and the Course of History 1500 to Today*, Gotham Books, New York, 2006, p. 16

10 National Intelligence Council, *NIC Global Trends 2017: Paradox of Progress*, 2017, p. 15, 17.

11 National Intelligence Council, *NIC Global Trends 2017: Paradox of Progress*, 2017, p. 177.

12 Baldwin, R., The Globotics Upheaval: Globalisation, Robotics and the Future of Work, Oxford University Press, New York, 2019, p. 187.

13 Baldwin, R., *The Globotics Upheaval: Globalisation, Robotics and the Future of Work*, Oxford University Press, New York, 2019, p. 90.

almost half, approximately 2.8 billion people.[14] Between 1960 and 1980, the world's urban population increased by 5.5 per cent. In the following 20 years (1980–2000), this percentage increased by 7.4 per cent. From 2000 to 2020, the urban population of the world has been estimated to have increased by 9.5 per cent.[15]

For military leaders, it is in the security environment that acceleration is most pressing. Over the past two decades, most contemporary leaders have witnessed profound changes not only in the pace at which they must undertake operations but also in the increasing speed with which they have to adapt between mission sets. They must also contend with the speed at which the media (and higher headquarters) are able to gain visibility of military actions at almost every echelon. And, this pace of change will only continue to speed up. Renowned academic, Michael O'Hanlon recently wrote that:

> technological change of relevance to military innovation may be faster and more consequential in the next 20 years than it has proven to be over the last 20. Notably, it is entirely possible that the ongoing, rapid pace of computer innovation may make the next two decades more revolutionary than the last two.[16]

And, as United States Chairman of the Joint Chiefs, General Dunford, recently stated, 'the accelerated speed of war ensures the ability to recover from early missteps is greatly reduced.'[17]

But perhaps the most profound implication is that, regardless of the industry, the generation of a competitive advantage is becoming more difficult. Moreover, when an advantage is generated it is likely to be more fleeting than in previous eras. Rita McGrath has recently written that we now exist in an era of transient advantage.[18] And, if institutions are to be successful they must spark continuous change and avoid the rigidity that leads to failure. It is through this lens of constantly evolving sources of advantage that nations must look to develop and pursue strategies that harness all aspects of national capacity, including their military power. A key element will be the development of a more advanced intellectual edge.

14 Source: United Nations Educational Scientific and Cultural Organization, http://www.unesco.org/education/tlsf/mods/theme_c/popups/mod13t01s009.html

15 These figures are drawn from the data sets that are part of the United Nations Population Division report, World Urbanisation Prospects 2018, available at https://population.un.org/wup/Country-Profiles/

16 O'Hanlon, M., *Forecasting Change in Military Technology, 2020-2040*, Brookings Institution, Washington DC, September 2018, p. 4.

17 Dunford, J., speech quoted at Garamone, J., 'Dunford: Speed of Military Decision-Making Must Exceed Speed of War' U.S. Department of Defense, 31 January 2017. Source: https://dod.defense.gov/News/Article/Article/1066045/dunford-speed-of-military-decision-making-must-exceed-speed-of-war/

18 The term transient advantage is used in her 2103 article on competitive strategy, in McGrath, R., 'Transient Advantage', *Harvard Business Review*, June 2013.

Generating advantage and the intellectual edge

An essential purpose of military institutions is to seek to generate advantage over known and potential adversaries. Historically, there have been four key sources of this advantage: geographic, technological, mass and intellectual.[19]

Geography has long played a central role in nations building a competitive advantage. As Gray has written, 'Geography is the most fundamental of factors which condition national outlooks on security problems and strategy solutions'.[20] However, the advantages of geography are not what they once were. The speed of connectivity in the contemporary world, long-range sea and air transport capabilities and the ability of individuals to move almost at will to any point on the globe means that geography no longer guarantees sovereignty.[21] And in the emerging domains of space and cyber activities geographic constraints or advantages are yet to have a significant role.

A second source of historic advantage has been technology. From Greek Fire[22] to crossbows, tanks to jet aircraft, the enigma machine to contemporary high-capacity computing[23], military institutions throughout history have sought a competitive edge through possessing better technology than their adversaries. Advanced technology has provided an edge for Western military forces for generations but the advantages it now generates are smaller than in the past. As recent publications, such as the 2018 United States National Defense Strategy Commission[24], have described, the technological edge that has been the preserve of Western military institutions for several centuries[25] has declined. Complicating this situation, as mentioned above,

19 Ryan, M., 'An Australian Intellectual Edge for Conflict and Competition in the 21st Century', *Centre of Gravity Paper No. 48*, Coral Bell School, Australian National University, March 2019.

20 Gray, C., *War, Peace and Victory: Strategy and Statecraft for the Next Century*, Simon and Schuster, New York, 1990, p. 14.

21 As the recent US National Defense Strategy notes, 'the homeland is no longer a sanctuary'. U.S. Department of Defense, Summary of the 2018 National Defense Strategy of the United States of America, 2018, p. 3. In 2000, the Australian Defence White paper noted that 'Australia is a secure country thanks to our geography…'. This phrase was absent in the 2016 edition of the same document. Commonwealth of Australia, Defence 2000: Our Future Defence Force, Canberra, 2000, p. 23.

22 Greek Fire was a napalm-like substance fired by ships of the Byzantine Empire. Used between the 7th and 12th centuries, its exact composition has been lost to history. Condliffe, J., 'Lost Treasures: The Napalm of Byzantium', New Scientist, 1 February 2012. Source: https://www.newscientist.com/article/mg21328502-400-lost-treasures-the-napalm-of-byzantium/

23 High capacity computing is the aggregation of computing power to deliver greater performance than traditional computers in order to address scientific or engineering problems. 'What is high performance computing?' Inside HPC. Source: https://insidehpc.com/hpc-basic-training/what-is-hpc/

24 United States Institute of Peace, *Providing for the Common Defense: The Assessment and Recommendations of the National Defense Strategy Commission*, Washington DC, 2018, p. viii.

25 This is examined in Morris, I., *Why the West Rules— for Now: The Patterns of History, and What They Reveal About the Future*, Farrar, Straus and Girroux, New York, 2010.

although nations might generate technological advantages these are likely to be more transient than in previous eras.[26]

A third source of historical military advantage has been mass. Generating a larger force than an adversary has long been the aspiration of military institutions. Whether to provide the capacity to concentrate forces and achieve local overmatch at the tactical level or used to provide the scale necessary to operate across many different parts of the globe, mass has played a crucial role in historical military success. Sun Tzu wrote that 'if we are concentrated into a single force while the enemy is fragmented into ten, then we attack him with ten times his strength'.[27] Clausewitz wrote that 'in tactics as in strategy, superiority of numbers is the most common element in victory'.[28] And, Jomini included mass in his 1838 *The Art of War* as a principle of war. Therefore, the doctrine of massed forces has influenced generations of military leaders. It remains a principle of war in the US military, most recently reinforced in the 2018 Joint Doctrine publication on operations.[29]

This conception of a larger military force however, does not include just the number of people in uniform.[30] As the US Civil War and two world wars demonstrated, successful military mobilisation also require efficient mass industrial mobilisation. In the first half of the 20th century, the US and the USSR[31] developed the capacity to mobilise large numbers of people but it was ensuring that industry could keep them adequately equipped, fed and supplied that became the acme of military skill.[32] However, these types of mass mobilisation and engagements also led to mass casualties. When the Soviets achieved nuclear parity with the US in the 1970s their overwhelming superiority in conventional forces was also a factor that led Western forces to focus on precision and economy of force through the Second Offset

26 The term transient advantage is borrowed from a 2103 article on competitive strategy, in McGrath, R., 'Transient Advantage', *Harvard Business Review*, June 2013.

27 Sun-Tzu, *The Art of War*, translated by Sawyer, R., Westview Press, Boulder, 1994, p. 192.

28 Von Clausewitz, C., *On War*, Book 3, Chapter 8, Superiority of Numbers, (Trans), Princeton University Press, Princeton, 1976, p. 194.

29 *US Joint Doctrine – Operations 2018*, US Department of Defense, Washington DC, 2018, p. ix.

30 At the start of the First World War, most European states had large conscripted armies. Keegan, J., *A History of Warfare*, Alfred Knopf, New York, 1993, p. 234.

31 Harrison, M., 'Resource Mobilization for World War II: the USA, UK, USSR and Germany, 1939-1945', *Economic History Review*, 41:2 (1988), pp. 171–192. The formation of the Red Army in the 1920s was founded on the ideas of Soviet military theorist and leader Mikhail Frunze, who authored a unitary military doctrine in 1921, which also included mass warfare that embraced the total mobilization of the state and peacetime compulsory military service. Rice, C., 'The Making of Soviet Strategy', Makers of Modern Strategy, Princeton University Press, Princeton, 1986, p. 655.

32 The United States military has recently re-issued its doctrine on military mobilization, in U.S. Joint Staff, Joint Publication 4-05, *Joint Mobilization Planning*, 23 October 2018.

strategy.[33] Coupled with post–Cold War draw downs,[34] Western nations now possess numerically smaller forces than their potential adversaries. They also have a significantly reduced capacity for large-scale industrial mobilisation to build military hardware[35]—at least at the start of any conflict.

Hence, Western military organisations face challenges to the three macro-sources of traditional military advantage. Sovereignty can no longer be guaranteed by geography, the advantages of technological are declining and Western militaries lack the mass of potential adversaries. Military organisations must therefore increase investment in the only remaining source available to offset the competitive advantages of potential adversaries by cultivating an *intellectual edge*.[36] It not only provides a source of strength and addresses the *software gap* but can also be used to bind other marginal sources of strength into a greater whole. This clever application of military forces (within a smart use of all aspects of national power) is built on the possession of the best ideas that are applied to tactics, operational concepts, strategy and organisations.

This intellectual edge manifests in two different but interconnected ways; the individual and the institutional.[37]

For an individual, the intellectual edge is the capacity to creatively out-think and outplan potential adversaries. The intellectual edge is founded on the broadest array of training, education and experience that can be provided by institutions, as well as by a personal dedication to continuous self-learning, over a long period of time. Increasingly, an individual's intellectual edge will be underpinned by cognitive support

33 In the 1950s, the US built a large nuclear force to 'offset' the Soviet advantage in conventional forces. However, when the Soviets achieved nuclear parity in the 1970s, the US needed to find another source of military advantage. Thereafter arose what became known as the 'Second Offset'. While the US could not afford to match the Soviets tank for tank, it could field smaller numbers of extremely capable, high-quality equipment, leap-ahead technologies, and associated operational concepts. Grant, R., 'The Second Offset', *Air Force Magazine*, The United States Air Force Association, July 2016, p. 32–33. Source: http://www.airforcemag.com/MagazineArchive/Documents/2016/July%202016/0716secondoffset.pdf

34 For example, in just the first decade after 1989, the US Army was reduced in size from nearly 800,000 regular soldiers to just under 500,000 soldiers. Kapp, L., and others, *How Big Should the US Army Be? Considerations for Congress*, Congressional Research Service, Washington DC, 2 September 2016, p. 2. Source: https://fas.org/sgp/crs/natsec/R44612.pdf Since the end of the Cold War, the US Navy has reduced from 592 active ships (including 14 carriers, 137 submarines and 214 cruisers, destroyers and frigates) to the force in 2016 of 275 active ships (including 10 carriers, 70 submarines and 93 cruisers, destroyers and frigates). 'US Ship Force Levels', US Naval History and Heritage Command. Source: https://www.history.navy.mil/research/histories/ship-histories/us-ship-force-levels.html#1986

35 This is discussed in Whitlock, J., 'The Army's Mobilization Problem', War Room (online), 13 October 2017. Source: https://warroom.armywarcollege.edu/articles/armys-mobilization-problem/; and Kepe, M., 'Preparing for the NATO summit: Why military mobility should be on the agenda', The RAND Blog, 26 February 2018. Source: https://www.rand.org/blog/2018/02/preparing-for-the-nato-summit-why-military-mobility.html

36 Ryan, M., 'An Australian Intellectual Edge for Conflict and Competition in the 21st Century', *Centre of Gravity Paper No. 48*, Coral Bell School, Australian National University, March 2019.

37 Ryan, M., 'An Australian Intellectual Edge for Conflict and Competition in the 21st Century', *Centre of Gravity Paper No. 48*, Coral Bell School, Australian National University, March 2019.

through human-artificial intelligence teaming. This has been described as 'System 3' thinking by Dr Frank Hoffman.[38]

The second manifestation of the intellectual edge is institutional. While the intellectual edge in individuals is vitally important, so too is a collective, institution-wide intellectual edge. This comprises an organisation's capacity to effectively harness the disparate and diverse intellects of its individuals to solve complex institutional problems in the short, medium and long term. This institutional intellectual edge must be applied to the challenges of force design, operational concepts, integration of kinetic and non-kinetic activities, personnel development and talent management. This institutional manifestation also demands excellent leaders.

The intellectual edge and artificial intelligence

Nations are challenged in the shifting security environment to build, sustain and adapt the intellectual edge in individuals and organisations. This is not a new challenge. What compounds the challenge, however, is the current historically unprecedented speed of change in the environment. This era of acceleration means nations must develop the ability to recognise change more quickly, develop or evolve their strategies more rapidly and do this continuously.

But how is this to be achieved? Against this background, it seems likely that traditional methods of training and educating even the most talented and dedicated individuals will not be able to keep pace. The relentless speed of change and the complexity of the strategic environment militaries will increasingly be required to operate in defies human capacity to adapt.

Given the enormous complexity of this problem, enhancing biological sources of the intellectual edge with silicon-based intelligence—AI— appears to offer one pathway to an enhanced advantage for nations in the 21st century as it brings together the macro-sources of technology and intellectual advantage.

This AI support promises to augment the creative and contextual abilities of humans, not displace them. One recent article has proposed that 'a human's *coup d'oeil* might be augmented by a data-fused *cyber d'oeil* that supports human decision-making'.[39] It will be an increasingly fundamental approach to master if humans are to retain a full measure of decision-authority in an environment of rapidly increasing tempo in military operations.

38 Hoffman, F., 'Healthy Scepticism about the Future of Disruptive Technology and Modern War', *Foreign Policy Research Institute*, 4 January 2019, source: https://www.fpri.org/article/2019/01/healthy-skepticism-about-the-future-of-disruptive-technology-and-modern-war/, accessed 7 January 2019.

39 Hoffman, F., 'Healthy Scepticism about the Future of Disruptive Technology and Modern War', *Foreign Policy Research Institute*, 4 January 2019. Source: https://www.fpri.org/article/2019/01/healthy-skepticism-about-the-future-of-disruptive-technology-and-modern-war/

Arguably, there are two foundational theories that may assist in the development of approaches in the use of artificial intelligence to assist human cognition. First, the foundational theory of the extended mind, which explores how human cognitive processes are extended in the world. It provides a framework for understanding how artificial intelligence could support human decision-making because it proposes that tools (even simple tools like writing utensils) outside of human biology can serve as extensions of human cognitive states and processes.[40] The second theory is that of AI-extenders. This is a nascent approach that explores how artificial intelligence can be applied to supporting human cognition (including decision-making and other capacities).[41]

Extending human cognition

In recent decades, the extended mind thesis has gained traction in cognitive science, the philosophy of mind, and epistemology. This thesis denies that cognition is limited to individual minds or brains.[42] A number of authors have argued that an individual's cognitive processes spread beyond biological boundaries but the provenance of the extended cognition thesis is commonly credited to Andy Clark and David Chalmers, 1998 paper, *The Extended Mind*.[43]

Their thesis describes how the tools that humans use to assist them to complete cognitive tasks can become seamlessly integrated into their biological capacities. The key idea is that tools and biological intelligence together play an indispensable role in bringing about human cognitive functions. One example is the important role that a pen and paper play for a mathematician in solving complex equations. The pen and paper function as part of a process that, if it were done in the head, would be recognised as part of the cognitive process. Tools such as GPS and computers provide similar functions for military personnel. These cognitive tools are more than just tools, they are incorporated as part of the mind.[44]

The extended mind thesis therefore offers a simple, useful and explainable theory for improving human cognition.[45] The use of technology could allow humans to extend beyond their biologically-based cognitive capabilities. This might permit humans to

40 Clark, A., and Chalmers, D., 'The Extended Mind', Analysis 58.1, January 1998, p. 7–19.

41 Hernandez-Orallo, J and Vold, K., 'AI Extenders: The Ethical and Societal Implication of Humans Cognitively Extended by AI', Association for the Advancement of Artificial Intelligence, 2019.

42 Arnau, E., Estany, A., González del Solar, R., & Sturm, T., 'The extended cognition thesis: Its significance for the philosophy of (cognitive) science', Philosophical Psychology, 27:1, 2014, p. 1.

43 Clark, A., and Chalmers, D., 'The Extended Mind', Analysis 58.1, January 1998, p. 7.

44 Hernandez-Orallo, J and Vold, K., 'AI Extenders: The Ethical and Societal Implication of Humans Cognitively Extended by AI', Association for the Advancement of Artificial Intelligence, 2019, p. 1.

45 Vold, K., Overcoming Deadlock: Scientific and Ethical Reasons to Embrace the Extended Mind Thesis, Philosophy and Society, Vol. 29, No. 4, 2019, p. 489.

be more capable and better at a range of different functions, if this external technology is appropriately and ethically integrated. 'Appropriate integration', for Clark and Chalmers, requires that information in these external technologies is highly accessible, reliable and constantly available. Meeting these conditions, it is argued that external tools can provide humans with extended or even novel cognitive capacities.[46] The construct of AI-extenders applies this notion of cognitive extension to more sophisticated tools that are imbued with artificial intelligence capacities.

AI-extenders

In a 2019 paper, Jose Hernandez-Orallo and Karina Vold[47] proposed that artificial intelligence might allow for the extension of human cognition to new capabilities not conceived when Clark and Chalmers published their article in 1998. This extension of human cognition with artificial intelligence is distinct from fully externalised use of artificial intelligence.[48] There is no autonomy for the artificial intelligence involved. It is truly an extension, rather than an independent agent.

There are a broad spectrum of functions where artificial intelligence may be used to extend cognition and permit the development of an AI-enhanced human intellectual edge. Hernandez-Orallo and Vold have proposed a range of different elements of human cognition that might benefit from AI-extenders. These would augment existing, biological cognitive processes to permit humans to think through problems and develop solutions in a way that would not be possible otherwise. Hernandez-Orallo and Vold offer a diverse set from which military and national security planners might draw examples for the institutional implementation of human-AI teaming.

Noting the imperfect understanding of how human cognition might be extended with AI, I would propose that our first steps into this new world should be with the most basic of cognitive functions that our people and our leaders apply routinely. There are five: (1) enhanced memory, (2) attention and search, (3) comprehension and expression, (4) planning and executing activities and (5) metacognition.

Enhanced memory: Recently, researchers at the University of Pennsylvania have shown how machine learning algorithms might be used to stimulate, decode and

46 Hernandez-Orallo, J and Vold, K., 'AI Extenders: The Ethical and Societal Implication of Humans Cognitively Extended by AI', Association for the Advancement of Artificial Intelligence, 2019, p. 1.

47 I am indebted to Dr Karina Vold for her advice and suggestions on how AI extenders may be applied to military decision making.

48 Hernandez-Orallo, J and Vold, K., 'AI Extenders: The Ethical and Societal Implication of Humans Cognitively Extended by AI', Association for the Advancement of Artificial Intelligence, 2019.

enhance memory.[49] In a different approach, Elon Musk's Neuralink[50] is researching a 'high bandwidth' connectivity between the brain and computers to allow a 'human-AI merger'.[51] The rapid advances in this field, as well in neurotechnology,[52] indicate that the enhancement and augmentation of humans through brain-computer interfaces is possible in the short to medium term.[53] The application of AI-extenders for enhanced memory is likely to have a large range of applications in the military and wider national security circles.[54]

Attention and search: Humans frequently ignore or overlook objects or activities. This can often comprise information that has deep longer-term importance but lacks shorter-term context. It is only in hindsight that the importance of some information within a larger picture is recognised. There are many examples that illustrate this, including the 'failure of imagination' discussed in the United States 9/11 Commission Report.[55] AI-extenders might allow individuals or teams to examine large amounts of information through multiple live-feeds and databases in order to identify things—or bring focus to issues—that humans or humans in different sized teams may otherwise overlook, discard due to group think, or fail to appropriately prioritise.[56]

Comprehension and expression: AI-extenders may provide humans, and human teams, with a significantly improved understanding of information. Systems monitoring various activities, events, individuals and groups might be able to report probabilities of events (for example enemy actions) or quantities (an adversary's size or industrial capacity to produce precision munitions) with very short lead times. Contemporary real time analytics such as IBM Z[57] and Amazon Kinesis[58] show promise, particularly for developing real time situational awareness at the tactical level.

49 Kahana, M., Ezzyat, Y., and others, 'Closed-loop stimulation of temporal cortex rescues functional networks and improves memory', Nature Communications No. 9, 6 February 2018. Source: https://www.nature.com/articles/s41467-017-02753-0

50 Neuralink is an Elon Musk company that aims to develop ultra-high bandwidth brain-machine interfaces to connect humans and computers. https://www.neuralink.com

51 Cuthbertson, A., 'Elon Musk Says Neuralink Machine That Connects Human Brain to Computers 'Coming Soon', The Independent, 22 April 2019. Source: https://www.independent.co.uk/life-style/gadgets-and-tech/news/elon-musk-twitter-neuralink-brain-machine-interface-computer-ai-a8880911.html

52 Hong, G., Lieber, C., 'Novel electrode technologies for neural recordings', *Nature Reviews*, 4 March 2019. Source: http://cml.harvard.edu/assets/Novel-electrode-technologies-for-neural-recordings.pdf

53 Near-term brain-computer interfaces will likely remain task-oriented. Lance, B., and others, 'Brain-Computer Interface Technologies in the Coming Decades', *Proceedings of the IEEE*, Vol. 100, May 2012, p. 1585.

54 Hernandez-Orallo, J and Vold, K., 'AI Extenders: The Ethical and Societal Implication of Humans Cognitively Extended by AI', Association for the Advancement of Artificial Intelligence, 2019.

55 Failure of imagination is examined over multiple pages in the 9/11 Report. See *The 9/11 Commission Report: Final Report of the National Commission on Terrorist Attacks Upon the United States*, 2004, p.339–348.

56 Hernandez-Orallo, J and Vold, K., 'AI Extenders: The Ethical and Societal Implication of Humans Cognitively Extended by AI', Association for the Advancement of Artificial Intelligence, 2019.

57 Details of the IBM real time analytics at https://www.ibm.com/us-en/marketplace/machine-learning-for-zos

58 Details of the Amazon Kinesis product is at https://aws.amazon.com/kinesis/?nc2=h_m1

Planning, deciding, executing activities: Military organisations operate across a range of organisational levels and timescales that demand well-honed short, medium and long term planning capabilities. These processes could be significantly enhanced and potentially sped up through the application of AI-extenders that could develop models of action, testing and comparing various activities against known and projected enemy capabilities—and then comparing different courses of action for their capacity to achieve higher-level outcomes. AI-extenders may also be able to model the networks and anticipate the decisions, actions and interests of people outside of deliberate or formal planning activities. The application of AI-extenders to support this will be founded on advances in high-capacity computing and the nascent field of Generative Adversarial Networks.[59]

Metacognition: Metacognition describes what an individual or system knows about its own cognition, or cognition in general. It is literally 'thinking about thinking'.[60] It can take many forms and includes the use of knowledge about when and how to use particular strategies for learning or problem-solving.[61] This is important in developing leaders who can be lifelong learners though their individual capacity to learn how to learn; it is vital for the adaptive capacity of individuals. Metacognition has also been a focus of recent research into AI, in order to provide mechanisms for increasingly complex systems to recognise and diagnose failures.[62] Given the 'black box' nature of many AI systems (people don't know how AI comes up with decisions),63 the design of metacognition into next generation AI also aims to provide greater assurance to human users.

This is not an exhaustive list of the potential functions of AI-extenders. As institutions begin to apply these AI-extenders to a widening array of activities, more functions

59 A Generative Adversarial Network a computerised model that is trained using two neural network models. One model is called the '*generator*' or '*generative network*', this learns to generate new plausible samples. The other model is called the '*discriminator*' or '*discriminative network*' and learns to differentiate generated examples from real examples. The two models are set up in a contest or a game (in a game theory sense) where the generator model seeks to fool the discriminator model. The application of this to scenario testing and wargaming friendly versus enemy actions is obvious. Marr, B., 'Artificial Intelligence Explained: What Are Generative Adversarial Networks?', Forbes, 12 June 2019. Source: https://www.forbes.com/sites/bernardmarr/2019/06/12/artificial-intelligence-explained-what-are-generative-adversarial-networks-gans/#186b870d7e00

60 Chick, N., "Metacognition", Vanderbilt University Centre for Teaching online, Source: https://cft.vanderbilt.edu/guides-sub-pages/metacognition/

61 Crowder, J., 'Metacognition and Metamemory Concepts for AI Systems', Conference Paper, July 2011.

62 Schmill, M., and others, 'The Role of Metacognition in Robust AI Systems', Association of for Advancement of Artificial Intelligence, 2008. Source: https://www.aaai.org/Papers/Workshops/2008/WS-08-07/WS08-07-026.pdf; Crowder, J., 'Metacognition and Metamemory Concepts for AI Systems', Conference Paper, July 2011. Source: https://www.researchgate.net/publication/235219069_Metacognition_and_Metamemory_Concepts_for_AI_Systems

63 This issue of AI as a black box is explore further explored in Bathaee, Y., 'The Artificial Intelligence Black Box and the Failure of Intent and Causation', Harvard Journal of Law & Technology, Volume 31, Number 2 Spring 2018; and, Bloomberg, J., 'Don't Trust Artificial Intelligence? Time to Open the AI Black Box', Forbes (online), 16 September 2018. Source: https://www.forbes.com/sites/jasonbloomberg/2018/09/16/dont-trust-artificial-intelligence-time-to-open-the-ai-black-box/#58f828fb3b4a

will be discovered. The functions provided here, however, suggest useful initial steps in exploring how an AI-extended intellectual edge might manifest in military and national security affairs. It is therefore worth exploring how the intellectual edge may be improved at the key levels of military activities, underpinned by AI-extenders.

Application of an AI-extended intellectual edge

There are two important military decision-making layers for the intellectual edge: tactical and strategic. However, these are not the only levels of decision-making relevant to military activities. Policymaking drives military strategy yet is largely the realm of civilian leadership. Operational decision-making is another layer, resting between tactics and strategy. Nonetheless, given that tactics and strategy sit at either end of the extremes of military decision-making, they are worthy of initial attention.

AI and tactical decision-making

At the tactical level, the intellectual edge is about success at the sharp end of military endeavours. Historically, this has been measured largely by physical actions within a complex context but it is increasingly shaped by cyber and other 'influence' activities. As artificial intelligence starts to be applied to tactical activities across the land, sea, air, cyber and space domains, it will start to change the balance of power in tactical military endeavours. Payne notes that this 'will change the utility of force by enhancing lethality and reducing risk to societies possessing AI-warfighting systems…a marginal technological advantage in AI is likely to have a disproportionate effect on the battlefield'.[64]

64 Payne, K., 'Artificial Intelligence: A Revolution in Strategic Affairs?', *Survival*, Vol. 06, no. 5, October–November 2018, p. 23.

Table 1: Tactical Applications of AI-extenders

AI-extender Functions	Tactical Applications
Enhanced Memory	Recall of previous incidents, enemy and friendly actions, supply states and other data more quickly that can then be applied rapidly for planning or hasty operations. This function might be underpinned by data visualisation, chatbots and other new machine-human interfaces. For example, a tactical leader may use a chatbot accompanied by data visualisation to search for information and order the application of different analytics to specific sets of tactical information.
Attention and Search	Current and future tactical leaders rarely suffer from a lack of information. Their challenge is to find relevant information and sort through this over-abundance of information for that which is tactically useful within a relevant amount of time. Therefore, AI-extenders might rapidly sort through still-imagery, video, voice, text and knowledge sources for relevant, near-term information (based on human mission-derived parameters) and then provide decision-support cues to all relevant human actors within a defined group of units and organisations.
Comprehension and Expression	The defining feature of future warfare will be speed. In many cases, the speed of operations or tactical actions may be beyond the comprehension of even the most exceptional humans. AI-extenders may be used to cue tactical commanders at all levels to rapidly emerging situations that require their attention, while providing initial pathways for decision-making. Another function can include translation between different languages, as well as identifying and making sense of body language and cross-cultural cues. This could support alliances and relationship building with different populations. Initial programs, such as Google Translate,[65] Microsoft Translator[66] and Amazon Comprehend[67] are contemporary AI that are available and continue to improve in quality. Finally, Robotic Process Automation (RPA) is an emerging form of technology based on the idea of software robots or artificial intelligence (AI) workers, which undertake high-repetition mundane tasks. This could be applied to many routine tasks, freeing humans to exercise creativity. Military institutions may eventually get to the point where each human is running at least one or more 'bots' that are undertaking RPA activities.
Planning, Deciding, Executing Activities	Support to tactical planning, both hasty and deliberate. In particular, support to formal decision-making processes including modelling unique courses of action, probabilistic risk assessments and wargaming / simulating the potential success of these actions against known and anticipated adversary capabilities, organisations, tactics and intentions. Rapid decision-support to derive optimum solutions across a range of endeavours which may also include network deployment and assurance, as well as the conduct of information operations and logistic support. Other functions that might benefit from AI-extenders include the optimal dissemination of orders across assured networks, and the improvement of monitoring of execution of tactical activities.
Metacognition	The application of AI-extenders in this area may assist the rapid assessment and feedback of desired versus actual outcomes for tactical actions. Support for short- and medium-term learning and dissemination of lessons about adversary tactics and capabilities might also be improved. Application of AI-extenders may also include improving organisational self-awareness of their own capacities, making them less susceptible to self-deception, and allow the optimisation of combined arms and joint capabilities across a defined area based on previous experiences of friendly and adversary organisations, and the optimisation of the information flows and logistic support for that force.

65 Google Translate can be found at https://translate.google.com

66 See Microsoft Translator at https://translator.microsoft.com

67 See details on the natural language processing of Amazon Comprehend at https://aws.amazon.com/comprehend/

Table 1 illustrates areas where an AI-extended intellectual edge might be used in tactical actions. AI has multiple possibilities for decision-support at the tactical application layer. A capacity to support alignment of tactical with higher aims is just the tip of the iceberg. Using *human in the loop* and *human on the loop* systems,[68] forms of AI may be applied for rapid decision-making. Other yet to be developed AI might support the integration of joint capabilities and assist in tactical planning through rapid simulation of the outcomes of multiple options.

AI-enabled Strategy

In many respects, strategic thought as well as the development and execution of strategy represents the ultimate manifestation of the intellectual edge for military professionals and other national security practitioners. Colin Gray has written that 'the most enduring function of strategy is management of potentially lethal dangers. Strategists need to be "right enough" to enable us to survive the perils of today, ready—and possibly able—to cope strategically with the crises of tomorrow'.[69] The *era of acceleration*[70] promises many potential pitfalls for strategy developers; the pace of change can disrupt strategic plans and planning more quickly than ever before.

Regardless of the types of disruptions that might be witnessed in the strategic environment, strategy will remain a central preoccupation of military institutions and national states. But, how it is developed and the speed at which it must evolve, is being disrupted. Table 2 describes how the five key AI-extender functions might be applied to strategy development and execution in the near future. Intellectual edge at the strategic level is a function of best matching purpose to action.[71]

The tactical and strategic levels of military endeavour are just two examples of how AI-extenders might be used in organisations. There are a range of other human endeavours across society, government and business that could potentially benefit from the use of AI-extenders to provide an 'extended intellectual edge'.

68 These forms of human-machine command and control relationships are explained in Scharre, P., and Horowitz, M., *An Introduction to Autonomy in Weapon Systems*, Center for a New American Security, Washington DC, February 2015, p. 6. Source: https://s3.amazonaws.com/files.cnas.org/documents/Ethical-Autonomy-Working-Paper_021015_v02.pdf

69 Gray, C., *The Future of Strategy,* Polity Press, Cambridge, 2015, p. 117.

70 This term was first used by Kurzweil and Meyer in an article titled 'Understanding the Accelerating Rate of Change'. Kurzweil, R., and Meyer, C., 'Understanding the Accelerating Rate of Change', *Perspectives on Business Innovation*, 1 May 2003. Source: https://www.kurzweilai.net/understanding-the-accelerating-rate-of-change

71 As Gray notes, strategy only has value when it serves as a bridge between purpose and action. Gray, C., The Future of Strategy, Polity Press, Cambridge, 2015, p. 23

Table 2: Strategic Application of AI-extenders

AI-extender Functions	Strategy Applications
Enhanced Memory	AI-extenders could play an important role in retaining corporate knowledge, particularly in military institutions where there is a regular turnover of personnel due to posting and operational turbulence. This will be especially important where the implementation of strategies over long periods of time is necessary. The extenders may also provide the enhanced memory function to assist personnel with previous examples of friendly and adversary strategic activities to assist in planning and adaptation, as well as provide memory support on optimal strategies for technology development, resource use in military activities and what has worked in attracting and keeping personnel in a military organisation.
Attention and Search	The increase in speed that is transforming tactical activities is also influencing the development and implementation of strategy. Bespoke, strategic level AI-extenders may be able to discern and highlight to strategic leaders the initial indicators of changes in the broader strategic environment. This will include the activities of competitors and adversaries but may also include cues about breakthroughs in disruptive technologies, new strategic concepts, changes in strategic logistical capacity and other resources applied to military operations. It may also provide support to strategic management, monitoring and problem-alerts in communications networks that cover space-based and terrestrial systems, and potentially uncover 'unknown unknowns' – unseen threats.
Comprehension and Expression	The contemporary strategic applications of influence operations, or political warfare, will play a much more prominent role in national security activities. The use of AI-extenders could assist in detecting and better understanding the linkages in a competitor's, or adversary's, political warfare activities, and discovering key 'influencers' to aid in targeting them. Conversely, AI-extenders may assist in measuring the progress, and recommending improvements, in friendly influence activities. AI-extenders may also be used in ensuring that different elements of a national security enterprise can better understand each other's motivations, priorities and key points of interaction within a larger national security construct.
Planning, Deciding, Executing Activities	Intelligent decision-support tools for human planners for development of a diverse array of options for dealing with strategic dilemmas—in strategic competition and conflict—might be developed. Additionally, informed and connected decision-support for the range of strategic enterprise functions—personnel management, logistics, base management and maintenance, to name a few—might be an important set of design drivers for AI-extenders in this area. For example, in personnel, existing personalisation AI such as Amazon *Personalise*[71] offer initial capability in decision-support for those involved in workforce planning activities. Another enterprise function, such as better predicting military expenditures, might be supported through contemporary AI, such as *Amazon Forecast*.[72]
Metacognition	Retention and enhanced sharing of lessons about strategic decision-making in the military institution, but also in allies and potential adversaries. This might extend to projections about potential strategies that could be adopted to adversaries and allies. This AI-extender function would represent an important manifestation of the intellectual edge at the institutional level, where the organisation not only continues improving its operations but also constantly learns about improving the capacity to enhance its planning, activities and adaptation at the strategic level.

72 See https://aws.amazon.com/personalize/

73 For details of this this, see https://aws.amazon.com/forecast/

The way ahead

Successfully achieving military and national security objectives in the 21st century will demand that military institutions realise the potential of their personnel in a way that nurtures and celebrates their intellectual edge with the support of appropriate artificial intelligence. It will require an institutional mindset that doesn't replace humans with machines but replaces some lower order human cognitive functions with bespoke AI. And, it will require a disciplined but adaptive institutional leadership to nurture and embrace organisational, conceptual and technological change. It is proposed that four areas of work will underpin this.

First, military institutions must possess an endorsed plan of how their personnel will make AI-supported decisions. In developing and executing this, there will be human and organisational barriers to overcome. While always challenging, these institutional changes can be aided by having a clear explanation of purpose for why AI will be used to support decision-making. This should form part of a more expansive view of future military capability and national security policy.

Second, military institutions will need to evolve their capacity for strategic engagement and scanning. Engagement between like-minded military institutions —between services and between like-minded nations—must embrace a greater sharing of ideas on the application of AI. Enhanced sharing—of the best-practice use of AI in developing a future intellectual edge—must be one of the cornerstones of the future approach to Western military alliances.

Third, military institutions must significantly improve their technological literacy. If military institutions are to effectively start using AI, they will need more than just deep technical experts in the development of algorithms and the design of AI for military systems. At almost every rank level, military personnel will require basic literacy in a spectrum of new and disruptive technologies, such as AI.[74] This must include knowledge of its application, how to provide a level of assurance and quality control, the ethical considerations and how to creatively combine it with new concepts and human organisations.[75]

Finally, military institutions must build 'checkpoints' to ensure that the use of AI is aligned with institutional values. The extension of human cognition with AI will pos-

74 This must include knowledge of its application, how to provide a level of assurance and quality control, and how to optimally combine it with new concepts and human organisations at every level. Ryan, M., 'Intellectual Preparation for Future War: How Artificial Intelligence Will Change Professional Military Education', War on the Rocks, 3 July 2018.

75 Approaches to achieving this are explored in Ryan, M., *Human Machine Teaming for Future Ground Forces*, Centre for Strategic and Budgetary Assessment, Washington DC, 25 April 2018.

sess ethical challenges[76] that must be addressed in parallel with technological developments. Some elements of augmenting humans with technology may challenge traditional notions of human decision-making. So, there is some way to go before humans place their full trust in the decision-making capacity of machines. But trust that machines will operate in way that is fair and aligned with the values of their human users is an essential element of effective human-AI teaming.[77]

Conclusion

One does not need to be an expert in all aspects of AI developments to recognise its potential for assisting military leaders with their cognitive processes. The capacity of humans to make sense of a world changing at a rapid pace is diminishing. Where we must make sense of information, and make decisions that involve life or death, some form of supplementation to human cognition is required.

The application of AI-extenders to achieve an extended intellectual edge represents the first steps that military institutions might take to improve the quality and responsiveness of decision-making by individuals and teams. These steps will also provide useful information about the micro-relationships that will form[78] between humans and AI to inform subsequent generations of human-AI teaming. This is an undertaking that will demand institutional leadership, the development of new visions of organisational purpose, [79] strategic focus, collaboration with industry and academia, and tolerance of risk and failure. But it is worth effort because it offers significant potential advantages to military decision-makers in the 'era of accelerations'.

76 Diakopoulos, N., 'Algorithmic Defamation: The Case of the Shameless Autocomplete', Tow Center for Digital Journalism website, August 6, 2013. Source: http://towcenter.org/algorithmic-defamation-the-case-of-the-shamelessautocomplete/

77 Establishing trust between humans and machines is a fundamental aspect of human machine teaming. I explored this issue in Ryan, M., *Human Machine Teaming for Future Ground Forces*, Centre for Strategic and Budgetary Assessment, Washington DC, 25 April 2018. It is also explored in Orallo, J and Vold, K., 'AI Extenders: The Ethical and Societal Implication of Humans Cognitively Extended by AI', Association for the Advancement of Artificial Intelligence, 2019; Paul Scharre and Michael C. Horowitz, An Introduction to Autonomy in Weapon Systems, working paper (Washington, DC: Center for a New American Security, February 2015, and numerous other publications.

78 Abbass, H., 'Social Integration of Artificial Intelligence: Functions, Automation Allocation Logic and Human-Autonomy Trust', *Cognitive Computation*, Vol. 11, 2019, p. 170.

79 Builder, C. and others, *The Army in a Changing World: The Role of Organisational Vision*, RAND Arroyo Center, RAND Corporation, Santa Monica, June 1990.