National Defence Défense nationale

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AI and Its Potential to Affect Military Power Balance

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JCSP 47

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CANADIAN FORCES COLLEGE – COLLÈGE DES FORCES CANADIENNES

JCSP 47 – PCEMI 47

2020 – 2021

MASTER OF DEFENCE STUDIES – MAÎTRISE EN ÉTUDES DE LA DÉFENSE

AI AND ITS POTENTIAL TO AFFECT MILITARY POWER BALANCE

By Major T.C. McRobbie

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Abstract

While research into Artificial Intelligence (AI) has been ongoing for decades the confluence of computing power, large data sets, and improved AI algorithms have brought the field to the point of practical application across virtually every domain. AI algorithms have already been widely employed in consumer electronics and services, with end-users generally oblivious to the technology. An examination of potential applications of AI algorithms to military operations through the Canadian Armed Forces doctrine of operational functions shows that this will create new capabilities while improving on extant ones. This crosscutting technology has implications in offensive and defensive weapons, military intelligence, communications systems, logistics, and command and control systems. The United States, China, and Russia have all published national strategies on AI, seeking to guide the development within their borders from both an economic and military perspective. The widespread development of AI weapon systems has developed into an arms race between the World's most powerful militaries. The current forerunner technologies within the field of AI are relatively nascent in terms of widespread application and development. Vulnerabilities have emerged, with researchers focused on both exploiting, and defending against these vulnerabilities. Researchers are mixed on predictions of whether AI systems will ever reach an equivalency to human cognitive capacity. From a military standpoint, this is irrelevant as the current level of AI sophistication is sufficient to dramatically increase a nations' military power. Implementation of AI into a nations military, gives countries the potential to improve their relative standing in the world with respect to military power.

CHAPTER 1 – INTRODUCTION

Human nature has always been inclined to create tools and discover new technologies to give us an advantage. Fire gave us heat in the cold, light in the darkness, and killed sickening microbes in our food. The wheel allowed us to efficiently move heavy loads over long distances. As time marches on, the rate at which humanity develops new technologies has been increasing whether through novel applications of existing technology or brand new areas of research. Many of the technological breakthroughs that have become commonplace, were originally developed for military applications. The development of the nuclear bomb later led to nuclear medicines and the current field of research into nuclear fusion power plants. The cold war brought about the global positioning system (GPS), which is incorporated into our phones, watches and computers. The development of nuclear weapons and GPS was a deliberate strategy by the United States, to use technological advantage as an offset to the numerically superior adversaries they potentially faced.[1] The times have changed now, and rather than the military pushing the rate of technological development, industry has been the leader.

Game playing artificial intelligence (AI) algorithms and systems capable of image recognition is now developed by private industry and universities across the globe. Business leaders see the opportunity to increase their productivity while decreasing costs, by automating their physical and intellectual workflows. The most advanced AI technology emerging in the last decade has come to the consumer marketplace before it landed in the hands of soldiers. This has created a new opportunity for military capability

[1] Paul Scharre, *Army of None: Autonomous Weapons and the Future of War*, First edition (New York ; London: W. W. Norton & Company, 2018), 59.

development, with the most powerful nations rushing to capitalize. AI has the capacity to improve some fields within the military, increasing the effectiveness while decreasing the resources required. Image recognition algorithms can augment and improve the output of human imagery analysts, both increasing the images, which can be processed while decreasing the number of personnel required for a set number of images. AI can also be used to create novel capabilities like swarming agents, which can collaboratively achieve tasks. AI is a powerful enabling technology, which will have a transformational effect on the world and has the potential to alter the balance power between the world's militaries. It is up to each power nation to invest their resources in the field of AI in order to achieve the transformational effect that it offers. The United States has claimed the moniker of the offset strategy, but any nation achieving dominance in the field of AI has the potential to use this advantage to offset the numerical or technological superiority of its allies. This essay will examine the field of AI with applicability to military usage in order to demonstrate how a military can apply it.

This paper will start by examining the historical background of AI research from its inception to present day. The chapter will define AI, explore the important milestones in the AI timeline, and explain the theory of how AI algorithms function. The chapter will conclude by examining the potential future of AI research.

Chapter three will examine the application of AI to a military using the Canadian doctrinal operational functions: Command, Act, Sense, Shield and Sustain. It will explore how AI can be used to achieve each operational function while describing the advantages

that the AI offers. It will look at a variety of technologies, which demonstrate the precursor platforms to AI, technologies under development, and future AI systems that may be developed for military use.

The fourth chapter will be an examination of the relative potential for the United States, China, and Russia to become the world leader in AI. It will examine the national AI strategy of each country and their financial and technological resources. The chapter will also assess the ethical considerations that each nation takes into account in the development of AI weapons for their militaries.

The fifth chapter of this paper will examine some of the potential issues with AI, which could hinder its application for a military. It will look at current vulnerabilities, ethical concerns and the uncertainty of future technological gains in order to explore the counterarguments to this thesis.

Despite the current hype around the future of AI, the field of research as been around for close to a century. The last decade of discoveries has been mirrored in the past by similar decades of advancements and hype. An examination of where AI started will aid in understanding where the technology will go and how it may be applied.

CHAPTER TWO – AI DEFINED

This chapter will focus on defining what is AI, how it evolved from its initial inceptions to its present level of sophistication, the different technologies that can be considered AI, and the theory of how they work. It will also look to forecast research priorities within the field of AI and examine how it may change. An examination of issues arising from ethical and societal implications will be saved for discussion in Chapter 5.

Defining what constitutes AI is open to interpretation as what constitutes intelligence is subjective. The artificial portion of the term is straightforward, indicating that the intelligence has been designed by people to replicate something natural.[2] Defining intelligence can impact how researchers attempt to create AI as they are attempting to make something that replicates naturally occurring intelligence. Stuart Russell, in what is considered the standard text in AI, examined intelligence in two dimensions: human versus rational and thought versus behavior. The human definition of AI compares the performance of an AI system to human performance. A rationality definition examines whether the AI is doing what it should.

The second dimension examines intelligence as a process that occurs internally (thought), or externally as a behavior.[3] The definition chosen for intelligence has led researchers to diverge in their approaches to developing it. Alan Turing, came up with an

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[2] "Cambridge Academic Content Dictionary" (Cambridge University Press), accessed March 2, 2021, https://dictionary.cambridge.org/dictionary/english/artificial.

[3] Stuart J. Russell and Peter Norvig, *Artificial Intelligence: A Modern Approach*, Fourth edition, Pearson Series in Artificial Intelligence (Hoboken: Pearson, 2021), 1.1.

experiment known as the *Turing Test*, which evaluates whether a computer or human is responding to question.[4] Anyone who has opened up a free email account, has encountered a version of the test known as the *Completely Automated Public Turing test to tell Computers and Humans Apart* (CAPTCHA) which is designed to prove that a human is using the service instead of a machine.[5]

From a military perspective, having a machine that can perform in the same manner as a human, and with a quality that matches or exceeds a human, would be incredibly useful. This is exemplified by the SOF truths that Special Operations Forces (SOF) worldwide have adopted. The truths were written by John M. Collins in 1987 and speak to the important principals that must be adhered to for effective SOF.[6] The first truth is that humans are more important than hardware and this speaks to the unique abilities that human's possess. Creating a machine that would perform with the unique abilities humans possess would reasonably be the goal of an AI system. Humans are imperfect though, our emotions, which make us uniquely human and allow us to enjoy life, also lead us to make mistakes. An exhausted and famished human will struggle to maintain the same rational level of performance that they achieved when rested and satiated. From a military standpoint then, the most useful definition of an AI system is

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[4] Gary Marcus, Francesca Rossi, and Manuela Veloso, "Beyond the Turing Test," *AI Magazine* 37, no. 1 (2016): 3–4, https://doi.org/10.1609/aimag.v37i1.2650.

[5] Kurt Alfred Kluever, "Evaluating the Usability and Security of a Video CAPTCHA" (Rochester Institute of Technology, 2008), 1.

[6] John M. Collins, *Green Berets, Seals, and Spetsnaz: U.S. and Soviet Special Military Operations*, 1st ed (Washington : Elmsford, N.Y., U.S.A: Pergamon-Brassey's ; Orders, Pergamon Press, 1987), Forward.

one that is rational and focused on achieving the correct output rather than doing it like a human.

Humans quantitatively measure intelligence using the Intelligence Quotient (IQ) system as a means to measure someone's cognitive control processes. This is an imperfect system though as it does not include a measure of the emotional intelligence and its impact on cognitive control processes.[7] Measuring a machine to determine at what point its actions have entered the realm of intelligence, likewise becomes difficult. A team of experts wrote a report on the implications of AI for the US DoD in 2017 and gave a loose definition of AI as "the ability of machines (computers) to perform tasks that humans do with their brains".[8] This loose definition enables us to classify many technologies that have existed over the last century as AI. Control systems for early rockets like the German developed V2 ballistic missile, could land a 1000 kg warhead to a range of 3500 km, landing within a circular error probability of 15-20 km.[9] Most would not consider these rudimentary guidance systems to be intelligent, especially in light of modern control systems. One of the most important areas of application for AI systems is in autonomy. The Society of Automotive Engineers has defined six levels of driving

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[7] Purificación Checa and Pablo Fernández-Berrocal, "The Role of Intelligence Quotient and Emotional Intelligence in Cognitive Control Processes," *Frontiers in Psychology* 6 (December 1, 2015), https://doi.org/10.3389/fpsyg.2015.01853.

[8] "Perspectives on Research in Artificial Intelligence and Artificial General Intelligence Relevant to DoD" (The MITRE Corporation, January 2017), 3.

[9] "V-2 (A-4)," in *Jane's Strategic Weapon System*, Obsolete Systems - Offensive/Defensive Weapon Systems, October 13, 2011.

automation with levels 0 to 2 being vehicles with a human driver enabled by support features while levels 3-5 are automated driving.[10]

Research into AI began in the early 20th century with a proposal of a mathematical model for artificial neurons. This model abstracted the functioning of how neurons work in the human brain, creating a mathematical network of nodes that could conceivably compute any function.[11] In his ubiquitous 1950 article, *Computing Machinery and Intelligence*, Alan Turing proposed that a machine with intelligence should be taught to learn instead of being programmed.[12] Turing recognized that programming every potential action and response into an AI system would be far more difficult than creating a system that could learn for itself. Major advancements in AI theory came out of the 1956 *Dartmouth Symposium*, a two-month long symposium consisting of 10 scholars in various fields and effectively marking the beginning of the field of AI.[13] Research in the field of AI continued over the next several decades with advances applied to virtually every field of life.

Scientists advertised their successes through exhibition games, demonstrating AI that could best human players in increasingly complex games. A program that could play

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[10] "J3016 Levels of Driving Automation," accessed March 2, 2021, https://www.sae.org/standards/content/j3016_201806/.

[11] Warren S. McCulloch and Walter Pitts, "A Logical Calculus of the Ideas Immanent in Nervous Activity," *Bulletin for Mathematical Biophysics* 5 (1943).

[12] Alan Turing, "Computing Machinery and Intelligence," *Mind* 59, no. 236 (October 1950): 455.

[13] Deyi Li and Yi Du, *Artificial Intelligence with Uncertainty*, Second edition (Boca Raton: CRC Press, Taylor & Francis Group, 2017), 32; Russell and Norvig, *Artificial Intelligence*, 1.3.1.

checkers was developed in 1952. IBMs Deep Blue chess playing software beat world champion, Garry Kasparov in 1997. Some of the world's best poker players were defeated in Texas Hold'em in 2017 by a computer program called Libratus. The Go playing program, AlphaGo beat the world's highest ranked player in 2016, immortalized in the documentary of the same name.[14] The sophistication and power of the various game-playing software is astounding. Deep Blue was considering over 100 million positions per second and occasionally was considering 40 moves into the future whereas modern AI chess programs can perform equally well while only needing to compute a million times per second and consider 20 moves into the future.[15] Go is considered a much harder game for an AI system to play than chess due to the vast number of moves available to each player. The completion of the first turn in chess results in one of 400 different results while in Go there are 129, 960 possible results. It is not computationally possible to evaluate every possible option in Go the way Deep Blue was doing in 1997.[16] Unlike Chess and Go, in Poker no player can have all the information about the cards that have been dealt. Poker strategy relies not only on playing the hand correctly but also in deceiving the opponent through deception. The *Deepstack* poker playing AI was engaged in human-like behavior when it beat the field of professional poker players.[17]

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[14] Greg Kohs, *AlphaGo* (A, 2017), https://youtu.be/WXuK6gekU1Y.

[15] Russell and Norvig, *Artificial Intelligence*, 353.

[16] Adam Levinovitz, "The Mystery of Go, the Ancient Game That Computers Still Can't Win," *Wired*, May 12, 2014, https://www.wired.com/2014/05/the-world-of-computer-go/#slide-1.

[17] Terrence J. Sejnowski, *The Deep Learning Revolution* (Cambridge, Massachusetts: The MIT Press, 2018), 33.

Demonstrating AI systems that can defeat humans at games is an attractive way to advertise success in the field. In reality, AI systems have been in use for decades in commercial products, many of which have military applications. Nick Bostrom, from Oxford University, remarked in 2006, "A lot of cutting edge AI has filtered into general applications, often without being called AI because once something becomes useful enough and common enough it's not labelled AI anymore."[18] In 2012, University of Toronto researchers demonstrated an image recognition system using AI algorithms (Deep Convolutional Neural Networks) to classify images with an error rate of 15.3%.[19] A decade later this powerful AI algorithm is accessible through the ubiquitous smartphones sitting in our pockets. Another AI technology used in our cellphones was developed by SoftMax who's algorithms using Independent Component Analysis (a form of Neural Network) to cancel background noise on devices using two microphones. Their foundational work is now used in cellphones worldwide, allowing users to better discern the speaker from the background noise.[20]

As computer speed rapidly improved into the 1970s and 1980s, AI programmers attempted to solve problems using a rules-based approach. This required compiling facts and rules from experts and then programming them into the computer so that it could apply these rules. The approach was made difficult by problems that required experts to

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[18] "AI Set to Exceed Human Brain Power," *CNN*, August 9, 2006, https://www.cnn.com/2006/TECH/science/07/24/ai.bostrom/.

[19] Alex Krizhevsky, Ilya Sutskever, and Geoffrey E. Hinton, "ImageNet Classification with Deep Convolutional Neural Networks," *NIPS' 12: Proceedings of the 25th International Conference on Neural Information Processing Systems* 1 (December 2012): 1097–1105, https://doi.org/10.5555/2999134.2999257.

[20] Sejnowski, *The Deep Learning Revolution*, 115.

use pattern recognition based on their experience and the difficulty of updating a system in a rapidly evolving field like medicine. These expert systems did not end up functioning well enough to be used in modern applications.[21] The fundamental algorithms that power modern AI systems were developed through the related endeavors of the field of cognitive science and AI research.[22] Researchers took inspiration from the neurons in brains to develop algorithms that could similarly function, though in an abstracted and superficial manner[23]. An example of this is the Hopfield net, which can be used for memory retrieval and is qualitatively based on the working of the human hippocampus.[24] Other sources of inspiration for AI development were evolutionary computation and swarm intelligence. These algorithms took advantage of the theory of natural selection as well as emergent behavior that develops when non-intelligent entities such as ants, interact.[25]

A Neural Network is an algorithm that consists of an input layer, hidden layers, and an output layer. Each of the hidden layers consists of multiple neural units, which are artificial neurons.[26] These neural units (technically incorrect but widely used simplified

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[21] Sejnowski, 53.

[22] Richard E. Neapolitan and Xia Jiang, *Artificial Intelligence: With an Introduction to Machine Learning*, Second edition, Chapman & Hall/CRC Artificial Intelligence and Robotics Series (Boca Raton: CRC Press, Taylor & Francis Group, 2018), 28; Sejnowski, *The Deep Learning Revolution*, 101–2.

[23] Russell and Norvig, *Artificial Intelligence*, Ch22; Ian Goodfellow, Yoshua Bengio, and Aaron Courville, *Deep Learning* (MIT Press, 2016), 16, http://www.deeplearningbook.org.

[24] J. J. Hopfield, "Neural Networks and Physical Systems with Emergent Collective Computational Abilities," *Proceedings of the National Academy of Sciences - PNAS* 79, no. 8 (1982): 2554–58, https://doi.org/10.1073/pnas.79.8.2554.

[25] Neapolitan and Jiang, *Artificial Intelligence*, 32.

[26] Neapolitan and Jiang, 32.

nomenclature is neurons) are interconnected and the output from one unit has an effect on multiple other units. The complexity of the neural network varies widely based on the requirements of the system though generally increasing the number of hidden layers will result in improved performance of the neural network.[27] The 2012 ImageNet neural network for example, contained 650, 000 neurons and the developers noted that for each hidden layer that was removed, a 2% loss in performance could be expected.[28]

As early AI researchers learned, it is not easy to program an algorithm with knowledge that it can make decisions on. The capability for an AI system to learn knowledge directly from data is known as machine learning.[29] Deep learning is a subset of machine learning that allows a computer to break down complex concepts into simpler constituent parts. An example of this would be a system that was fed a picture made of pixels, it finds edges in the picture and uses this to find corners and contours, which then allow it to find parts of an object, and finally it classifies the object.[30] The deep learning field of AI research has dramatically improved the performance of AI systems in tasks such as computer vision, and speech recognition.[31] The field of deep learning originated in the 1940s and its popularity waxed and waned over the ensuing decades. Originally called cybernetics, it was reinvigorated under the nomenclature connectionism and neural

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[27] Russell and Norvig, *Artificial Intelligence*, 1413.

[28] Alex Krizhevsky, Ilya Sutskever, and Geoffrey E. Hinton, "ImageNet Classification with Deep Convolutional Neural Networks," 8.

[29] Ian Goodfellow, Yoshua Bengio, and Aaron Courville, *Deep Learning*, 1–2.

[30] Ian Goodfellow, Yoshua Bengio, and Aaron Courville, 5–6.

[31] Russell and Norvig, *Artificial Intelligence*, 1414; Neapolitan and Jiang, *Artificial Intelligence*, 32.

networks in the 1980s-90s and is now commonly referred to as deep learning.[32] The modern resurgence of interest in deep learning uses algorithms that had been developed decades earlier but only became useful in the mid 2000s due to a confluence of three factors. These factors were the availability of large datasets or big data, which could be used to train the AI systems.[33] The second factor was the computational power that became readily available at the time. Chipmakers began making separate hardware components in computers for processing graphics, known as graphical processing units or GPUs. The hardware architecture of the GPUs enabled the training of larger networks with more layers.[34] The third factor was the improvement in deep learning algorithms, originated by Hinton's greedy layer wise algorithm developed in 2006.[35] These algorithms enabled more efficient and effective training of networks, improving the speed that they could be trained while decreasing the processing power needed to train them.

Deep Learning is not the only field of AI research currently being conducted and other areas hold promise for advances.[36] Unsupervised learning systems use machine learning on unlabeled data in order to find patterns within the data. These systems have

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[32] Ian Goodfellow, Yoshua Bengio, and Aaron Courville, *Deep Learning*, 13.

[33] Ian Goodfellow, Yoshua Bengio, and Aaron Courville, 19.

[34] "Perspectives on Research in Artificial Intelligence and Artificial General Intelligence Relevant to DoD," 1.

[35] Geoffrey E. Hinton, Simon Osindero, and Yee-Whye Teh, "A Fast Learning Algorithm for Deep Belief Nets," *Neural Computation* 18, no. 7 (2006): 1527–54, https://doi.org/10.1162/neco.2006.18.7.1527.

[36] "Perspectives on Research in Artificial Intelligence and Artificial General Intelligence Relevant to DoD," 2.

potential applications in medical diagnosis.[37] Reinforcement learning systems are assigned a goal and then continually iterate their process, learning which iterations bring them closer to their goal and which bring them farther away. Researchers have had success in game winning algorithms, which are given the video feed for a game and assigned the goal of maximizing the score. The program AlphaZero was able to teach itself how to play Chess, Go and shogi, using reinforcement learning and beat existing best in class programs for each game.[38]

Noteworthy in all of the AI advances to date is that they excel at completing narrowly defined tasks but can not be repurposed on the fly to complete other tasks. At times, these tasks may appear to be broad, as the example of AlphaZero learning to play multiple different games. These AI systems are defined as Narrow AI due to their inflexibility towards solving problems in general.[39] A general AI system would be one that learns in more human-like ways, has the flexibility to learn a multitude of tasks, use

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[37] Paul Scharre, Michael C. Horowitz, and Robert O. Work, "Artificial Intelligence What Every Policymaker Needs to Know," Artificial Intelligence and International Security (Washington, DC: Centre for a New Armerican Security, June 2018), 5.

[38] David Silver et al., "A General Reinforcement Learning Algorithm That Masters Chess, Shogi, and Go through Self-Play," *Science* 362, no. 6419 (December 7, 2018): 1140, https://doi.org/10.1126/science.aar6404.

[39] Greg Allen and Taniel Chan, "Artificial Intelligence and National Security," *Policy File* (Center for a New American Security, 2017), 8, http://cfc.summon.serialssolutions.com/2.0.0/link/0/eLvHCXMwY2AwNtIz0EUrE5KNLYA1hYFlKqh9nmpklpxmbplqlGKQAqxxEw3BVxP4uJv4RpkH-VpEQvuNoK0x0OiGlZLgojslPxk0aq4PbHqYmoNmhsyYGViNzIDtZBYGVkf_CG8XjHIVXFm4CTAEwsxNTkvWy0zJhW95RjuDkXirBRnYIC1lIQam1DwRBl3HIvAaH2DiUfBEOlRTITEvRQF61HWOQjD0bjpRBg031xBnD12YLfHAyAWN2CfmpQI7_vEIe4zEGHgTQWve80rAe-NSJBgU0hKNk1NNUyyNUs3STFJTgCFqnGxqkGRokmZglGhgmCTJoEjQXCki1EgzcBmBKjPQcZJGMgysacCMkSrLwAwMRDloiAMAYDCUoA.

inference and intuition for learning new things instead of only learning from examples.[40] It is virtually impossible to estimate when research will progress to the point that general AI systems are readily available. It is possible that much like the expert AI systems created in the 1980s, the current field of AI research will not have the potential to be developed into general AI. In 2014, a survey of AI experts predicted that there was a 50% chance that general AI would be created by the 2040-50 timeframe.[41] In part, varying estimates on when and if general AI will be achieved are based on the lack of a universal definition or test that would qualify a system as general AI. In spite of the fact that we are likely decades away from achieving a general AI which can function on par with humans, the current narrow AI systems and those that will be developed in the near future, are incredibly useful.[42] The increasing integration of AI technology will continue to transform how the world functions, most importantly transforming how the world's militaries operate.

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[40] Phil Torres, "The Possibility and Risks of Artificial General Intelligence," *Bulletin of the Atomic Scientists: Special Issue: The Global Competition for AI Dominance* 75, no. 3 (2019): 1, https://doi.org/10.1080/00963402.2019.1604873.

[41] Vincent Müller and Nick Bostrom, "Future Progress in Artificial Intelligence: A Survey of Expert Opinion," in *AI Matters*, vol. 1, 2016, 553, https://doi.org/10.1007/978-3-319-26485-1_33.

[42] Paul Scharre, Michael C. Horowitz, and Robert O. Work, "Artificial Intelligence What Every Policymaker Needs to Know," 4.

CHAPTER 3 – AI APPLIED

Militaries globally are constantly seeking an advantage over one another, both on and off the battlefield. AI has already enabled countless technological advancements, improving the tools that militaries use and holds tremendous potential for future advancements.[43] The integration of these new AI technologies into modern militaries will transform every aspect of how they do business. Countries that do not participate in the research and procurement of these technologies will find that in relative terms, their military power drops. This chapter will examine how AI is currently employed within militaries, advances and changes that are expected in the near future, as well as long term possibilities. The chapter will explore what the relevant technologies are, their advantages and their disadvantages. This examination will be conducted by considering the technological impacts of AI across the five operational functions of a military as defined by the Canadian Armed Forces: Command, Act, Sense, Shield and Sustain.[44]

The act domain covers the most dramatic examples of AI integration into a military context. The operational function act, covers the integration of manoeuvre, firepower and information operations.[45] Military weapons can range from automatic, automated to autonomous with important distinctions and capabilities existing at each level. Militaries have used automatic weapon systems for decades. An automatic weapon

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[43] "Perspectives on Research in Artificial Intelligence and Artificial General Intelligence Relevant to DoD," 53.

[44] Department of National Defence, *B-GJ-005-500/FP-000, CFJP 5.0 The Canadian Forces Operational Planning Process (OPP)* (Ottawa, Canada: DND, 2008), 2-8 — 2-10.

[45] "CFJP 3.0 - Operations" (Department of National Defence, September 2011), 1–5.

is one that will automatically function if a condition is satisfied.[46] Automatic weapons such as the Canadian C-9 Light Machine Gun, are a simple example where the weapon will automatically operate if the trigger is depressed. The delayed start function on an oven is another example where once the time condition has been satisfied, the oven automatically turns on the heating element.

Automated weapons are ones that use increasingly complex rules based considerations in order to function but their workings are not a mystery to the user.[47] This definition does not make a firm distinction between automated and autonomous weapons as the level of complexity can be subjective. Autonomous weapons would be the final level of autonomy by the weapons, essentially a weapon that operates on its own. This is still an overly broad categorization which can be subdivided into semiautonomous, supervised autonomous, and fully autonomous.[48] The US Department of Defense defines autonomous weapon systems in their Directive 30000.09 on Autonomy in Weapon Systems as, "A weapon system that, once activated, can select and engage targets without further intervention by a human operator."[49] This is not a globally accepted definition of autonomous weapon systems. For many countries, the legal, ethical, and political considerations that come along with the term autonomous are unpalatable. The UK defines fully autonomous weapon systems as, "machines with the ability to understand

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[46] Scharre, *Army of None*, 30.
[47] Scharre, 31.
[48] Scharre, 28.
[49] "Perspectives on Research in Artificial Intelligence and Artificial General Intelligence Relevant to DoD"; "Directive 3000.09 - Autonomy in Weapon Systems" (Department of Defence, May 8, 2017), 13, https://www.esd.whs.mil/portals/54/documents/dd/issuances/ dodd/300009p.pdf.

higher-level intent, being capable of deciding a course of action without depending on human oversight and control."[50] The UK has essentially reserved the definition of autonomous weapons to ones that possess or exceed a human-level of intelligence, which would be a general AI system as opposed to the narrow systems that exist today.[51] This definition draws a distinction between weapons that can operate on their own but are essentially following a pre-programmed set of instructions. The importance here is that humans (or a human) have pre-programmed the instructions, allowed the weapon system to follow the instructions, and understands how the system will react based on different factors. In the UK definition, an autonomous weapon could essentially choose its own criteria for action within limits. The DoD definition lends itself to the current definition of narrow AI, allowing it to apply to technologies available in weapons today.

The advent of AI did not create the field of weapons that are known as autonomous. One could argue that the Second World War era Bat, a radar-guided anti-ship bomb was an autonomous weapon. A human did the initial targeting but in the terminal phase of the engagement, the bomb used an S-band radar to detect the target, lock on to it, and engage.[52] The Bat was thus more precisely defined as a semi-autonomous weapon. A more modern version is the US Navy's Aegis Weapon System, first installed in 1973 on the test ship USS Norton Sound.[53] This continuously upgraded system fires ship-borne guided missiles defensively against incoming targets. The system

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[50] "Unmanned Aircraft Systems" (UK Ministry of Defence, August 2017), 43.
[51] Scharre, *Army of None*, 110.
[52] Scharre, 96.
[53] Louis A. Del Monte, *Genius Weapons: Artificial Intelligence, Autonomous Weaponry, and the Future of Warfare* (Amherst, New York: Prometheus Books, 2018), 72.

is varyingly described as semiautonomous by Louis Del Monte and automated by Paul Scharre.[54] The AEGIS has a variety of engagement modes ranging from manual, which requires a human to conduct engagements against targets, to Auto-Special, which completely automates the engagement of targets, which meet pre-defined parameters.[55] Noteworthy in the AEGIS system are doctrine, sets pre-determined parameters, which are designed, based on the anticipated environments in which a ship will be operating. This allows a ship's Captain to ensure that the AEGIS system is only as automated as the threat requires, and minimize the risk of accidently engaging friendly forces or civilians. In 1988 the USS Vincennes used its AEGIS system to shoot down an Iranian civilian passenger jet, killing all passengers aboard. In that incident, the error was attributable to the human operators who overwhelmed by the situation, mistook the passenger jet for an Iranian F-14. Allowing the AEGIS system to operate autonomously likely would have prevented the tragedy as the correct interpretation of all available information at the time was that the passenger jet was indeed a passenger jet.[56] The AEGIS would be considered automated using UK doctrine, based on the human programming of the doctrine.

One of the key advantages of autonomous AI systems is its potential to make warfare a safer endeavor. In a 2016 World Economic Forum, attendees voted 55% in favour of preferring autonomous AI weapon systems defending them rather than their

[54] Del Monte, 73; Scharre, *Army of None*, 89.
[55] Scharre, *Army of None*, 163.
[56] Scharre, 170.

people.[57] Losing robots on the battlefield will not have the same impact on the political party that sent them compared to losing soldiers.[58] AI has the potential to improve decision-making, accuracy and avoiding the foibles of humanity. AI enabled systems have the potential to reduce accidental deaths, civilian casualties and friendly-fire incidents.[59] Militaries and police forces routinely use robots for extremely dangerous tasks such as bomb disposal as it allows them to transfer some of the physical risks from the operator to the while allowing for the operator to use their expertise, knowledge and judgment in dealing with the bomb.[60] The US military used the PackBot robot to disarm over 10 000 improvised explosive devices in Iraq between 2003—2008.[61] The addition of an AI controller to the robot may further improve the performance of the robot, decreasing the risk of damaging homes, livelihoods and key infrastructure. Autonomous weapons imbued with AI have the potential to create a safer environment for the military force using them and for the civilian populace that is proximate to their use.

One of the main advantages (or dangers) of autonomous weapon systems is that they are expected to be able to operate in future combat environments that have degraded or non-existent communication links back to human controllers.[62] The degraded

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[57] Branka Marijan, "On Killer Robots and Human Control," *Ploughshares Monitor* 37, no. 2 (Summer 2016), https://ploughshares.ca/pl_publications/on-killer-robots-and-human-control/.

[58] Del Monte, *Genius Weapons*, 13.

[59] Scharre, *Army of None*, 6.

[60] Scharre, 15.

[61] William Merrin, *Digital War: A Critical Introduction* (London ; New York: Routledge Taylor & Francis Group, 2019), 418.

[62] Kelley M. Sayler, "Defense Primer: U.S. Policy on Lethal Autonomous Weapon Systems" (Washington, D.C.: Congressional Research Service, December 1, 2020), 1, https://fas.org/sgp/crs/natsec/IF11150.pdf.

communications environment is one that Canada and its allies have been growing concerned with over the last decade.[63] A fully autonomous weapon has no technological need to communicate back to its human overseer and can thus operate within a communications denied environment, identifying targets and attacking them. This creates moral concerns regarding the ethical use of autonomous weapons, as there is no human-in-the-loop to stop the system in the event it targets civilians or engages a target that would not be in the interests of the country that owned the weapon. An alternative function would be for the weapon to autonomously return for re-use rather than being lost when communications are severed.[64] Modern missiles are incredibly expensive so commanders will avoid using them if they think there is a possibility of wasting the weapon.[65] Precise costs are difficult to determine as factors such as missile type, number of units procured, and related support are aggregated in reported costs. An illustrative example is the 2019 Japanese procurement of 73 Standard Missile-3 Block IIA interceptor missiles for its Aegis system at an estimated cost of $3.295 billion, which would give a rough cost of $45 million per missile.[66] The autonomous weapon mitigates the concern of loss by offering a recovery option if no target can be located or engaged.

The automation of fighting vehicles has the potential to increase the range that they can operate, increasing their utility. Unmanned combat aerial vehicles (UCAVs) like

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[63] "Future Land Warfare Report 2014" (Canberra: Directorate of Future land Warfare, April 2014), 11.

[64] Scharre, *Army of None*, 328.

[65] Scharre, 54.

[66] "$3.3 Billion Sale to Japan of 73 SM-3 Ballistic Missile Interceptors Approved," *The Defense Post*, August 28, 2019, https://www.thedefensepost.com/2019/08/28/us-japan-sm-3-ballistic-missile-interceptors/.

the Navy's X-47B drone have the potential to operate at increased ranges compared to conventional aircraft like the F-18 or F-35.[67] The X-47B is a developmental aircraft, which can semi-autonomously takeoff, and land from an aircraft carrier as well as conduct aerial refueling.[68] While many aircraft have been able to takeoff on their own from land-based airfields, the small moving runway adds complexity to the process. Unmanned fighter aircraft can operate at extremes limited by their physical characteristics instead of being limited by the human within them. Pilot fatigue can be alleviated in a bomber by swapping out pilots, but in traditional jets like the F-35, the single pilot becomes a limiting factor in terms of flight endurance. AI algorithms also offer the possibility of faster reaction times than a human, giving them a distinct advantage. A 2016 simulation exercise pitted a human fighter pilot versus an AI powered pilot, showing the computer to outperform the human.[69] Simulations are heavily bounded and abstract many of the aspects of operating a complex machine so broad conclusions about real world application should not be drawn from this study. Instead, it is indicative of the potential for AI algorithms to outperform humans in tactical tasks.

An important advantage to AI enabled autonomous systems is their potential to be low cost and create entirely new capabilities. Remotely piloted drones are being mass produced for recreational markets, enabling users to film themselves from an overhead platform. Quadrocopter drones like the Hexo or the DJI series of drones with their

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[67] Scharre, *Army of None*, 62.

[68] "X-47B-UCAS Makes Aviation History...Again," 47, accessed March 4, 2021, https://www.northropgrumman.com/what-we-do/air/x-47b-ucas/.

[69] Nicholas Ernest and David Carroll, "Genetic Fuzzy Based Artificial Intelligence for Unmanned Combat Aerial Vehicle Control in Simulated Air Combat Missions," *Journal of Defense Management* 06, no. 01 (2016), https://doi.org/10.4172/2167-0374.1000144.

ActiveTrack technology are readily available at a cost of approximately $1,000.00.[70] These drones use a combination of GPS homing, vision and sensors to autonomously follow their target and possess the ability to avoid obstacles as they track. They are not a military grade product, require a limited speed while following, and are known to occasionally crash into obstacles. Their low cost may make up for this as they can be purchased in quantity and weaponized with a small payload. A study of ISIS propaganda imagery showed that the terrorist group has been using weaponized drones for attacks on Peshmerga soldiers since 2016 and destroyed a large Syrian army ammunition depot with to drone dropped IEDs in 2017.[71] The group also used commercial drones like the DJI Phantom for reconnaissance activities in preparation for future attacks.[72] The fact that the imagery from the study was all propaganda material published by ISIS makes it impossible to ascertain the success to failure ratio of attacks using drones but it does demonstrate the viability of drone technology for terrorist activities.

The weaponization of the DJI drones illustrates the power shift that comes along with AI-enabled weapons and suggests future opportunities for non-state actors to take advantage of new AI discoveries. Many advanced technologies have been developed first by military research and development and over time diffused to the commercial and private sectors. The development of the Global Positioning System by the US DoD is an

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[70] "Hexo+," Commercial, accessed March 5, 2021, https://hexoplus.com/; "How to Film Like a Pro: DJI Drone 'ActiveTrack' Video Tutorial (2020)," *Dji Guides* (blog), December 18, 2017, https://store.dji.com/guides/film-like-a-pro-with-activetrack.

[71] Emil Archambault and Yannick Veilleux-Lepage, "Drone Imagery in Islamic State Propaganda: Flying like a State," *International Affairs* 96, no. 4 (July 1, 2020): 966, https://doi.org/10.1093/ia/iiaa014.

[72] Archambault and Veilleux-Lepage, 966.

example of military developed technology that is now commonplace.[73] The new face of technological advancement is coming from commercial companies, which use,

> AI systems cable of aiding search and purchasing, presenting individually targeted recommendations, information, news and ads, organizing stock and warehousing operations and enabling voice and home assistants.[74]

AI enabled technology is now moving from the commercial realm to the military realm, which opens up its use to anyone with the funds to purchase it. Mass production of AI enabled technology allows for high research and development costs to be distributed over huge quantities of sales, driving down the cost. This democratizes the technology, allowing both ally and adversary to procure the same capabilities and diminishing the power of more advanced nations' militaries. Open source AI software can be freely used and integrated into a variety of platforms. The Chinese National Strategy for AI promotes open source software and technology programs as well as military and civilian sharing of the technology.[75] One example of this is YOLO, an image recognition algorithm developed by two doctoral students. The algorithm uses convolutional neural networks to analyze images in real time and can both locate the objects within a frame of a video, and identify the objects, expressing a confidence value of how certain the software is of its prediction. There is currently a version of the software designed to run on a cell phone,

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[73] Alexander C. T Geppert, Daniel Brandau, and Tilmann Siebenneichner, *Militarizing Outer Space: Astroculture, Dystopia and the Cold War*, 2021, 343–67.

[74] Merrin, *Digital War*, 425.

[75] Chinese State Council, "A New Generation of Artificial Intelligence Development Plan," Strategy Document, July 8, 2017.

demonstrating the limited computing power required for accurate computerized image recognition.[76]

The integration of open-source software like this into a military grade system would require substantial effort to ensure its reliability, maintainability, accountability, verifiability, and attackability but many of those "ilities" could be ignored by a terrorist force or nation willing to cut costs in order to integrate advanced technology.[77] An inexpensive drone, coupled with open-source software could be engineered to autonomously perform reconnaissance, highlighting objects or areas of interest to be reported back. An example of this is an open-source blog post detailing the construction and software for an autonomous drone, which uses AI to detect and report back in real-time on fires.[78] Assassination drones could be automated by using facial recognition algorithms to identify a target and attack it with a simple explosive payload. The low cost of these systems would allow for attackers to overcome potential quality issues by using quantity of platforms to conduct a saturation attack.

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[76] Andrea Missinato, "YOLO: An Ultra-Fast Open Source Algorith for Real-Time Computer Vision," *Nonteek* (blog), June 19, 2018, https://www.nonteek.com/en/yolo-real-time-object-detection/.

[77] "Perspectives on Research in Artificial Intelligence and Artificial General Intelligence Relevant to DoD," 2.

[78] Benjamin Nguyen and Jeremy Li, "FireFlight - Autonomous Responder and REconnaissance Drone," *Hackster* (blog), February 3, 2020, https://www.hackster.io/fireflight/fireflight-autonomous-responder-and-reconnaissance-drone-4656cd.

Another capability of low cost drones is their capacity to be networked and autonomously fly as a distributed swarm.[79] Swarming is a nearly century old tactic used by the German U-boats in World War II to attack convoys in the Atlantic Ocean. The US military also used the swarming tactic against the Japanese in the Pacific Ocean.[80] Using a multitude of connected drones could allow for resilience, efficiency and overall lower operating costs compared to larger platforms.[81] Swarms have virtually unlimited applications in both commercial, recreational and defense sectors. Swarms could cover a large search area and combine attack capabilities to engage targets when detected. If outfitted with chemical, biological, radiological and nuclear detectors, they could perform a defensive role at home or on the battlefield.[82] Commercial applications of drone swarms include the automated monitoring of critical infrastructure, decreasing the requirement for human involvement and performing the work in an economical manner.[83] There are over 840, 000 km of pipelines across Canada, transporting oil and natural gas from its source to refineries, ports and ultimately point of use. Networks of automated drones could enable monitoring of these pipelines for environmental damage, sabotage, and other signs of wear. A similar application in a military setting would be for continuous monitoring of key supply routes, battlefields, bridges, and other points of interest. By autonomously covering large areas and identifying points of interest, the drones could improve detection as well as focus intelligence analysts to points of interest.

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[79] Martti Lehto and Bill Hutchinson, "Mini-Drones Swarms and Their Potential in Conflict Situations," *International Conference on Cyber Warfare and Security*, 2020, 326-334,XV, https://doi.org/10.34190/ICCWS.20.084.

[80] Del Monte, *Genius Weapons*, 117.

[81] Lehto and Hutchinson, "Mini-Drones Swarms and Their Potential in Conflict Situations," 330.

[82] Lehto and Hutchinson, 330.

[83] Lehto and Hutchinson, 329.

Drone swarms can also serve to as a part of a defensive suite. In addition to performing reconnaissance, swarms could attack incoming munitions such as ballistic missiles. The swarm would manoeuvre to intercept the incoming missile and use its own kinetic speed to damage the missile upon impact, as well as incorporating explosive charges, detonated by the impact.[84] The US Navy has been developing swarmboats to defend their ships and offensively engage attackers. The addition of AI to the swarmboats allows them to distinguish friendly targets from hostile targets and enables the swarm to autonomously direct certain crafts to attack while maintaining defenses with the remainder of the swarm.[85] The AI would need to be coupled with appropriate sensors in order to accurately discriminate between hostile targets and decoys. The small size of swarmboats, and relative simplicity is coupled with the power of AI and big data to create a watercraft that could be manufactured inexpensively and in large quantities. In an offensive role, these swarmboats could be used to blockade an enemy port, acting like a fleet of autonomous mines to deter the enemy ships from departing.[86] The key in both the missile defense and port blockade is the swarm's ability to saturate an environment and attack or defend, which a high level of precision. An adversary could wait-out a barrage in the past, safe in their bunker, but a wave of precision weapons in the form of a swarm will force them to actively defend against each element of the swarm.[87]

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[84] Lehto and Hutchinson, 330.
[85] Del Monte, *Genius Weapons*, 119.
[86] Del Monte, 120.
[87] Scharre, *Army of None*, 45.

Drones are not impervious to attack and their AI enabled processors while improving their usefulness will not make them immune to threats. Israeli company, D-Fend, has created a technology, which allows them to track drones, take over their control, and force them to land in a safe location. The company claims that they have successfully taken over 10 drones in real life scenarios.[88] Drone swarms must be able to communicate with each other or they lose the advantage that comes from working cooperatively. The swarms must be hardened to overcome the inevitable defenses that an adversary will develop to protect against them. Novel ideas such as stigmergy, an indirect communication method used by ants to communicate, may offer solutions.[89] The speed of technological advance has enabled the rapid development of autonomous drone swarms. The US Army's Micro Autonomous Systems and Technology (MAST) program ran from 2008 to 2017. The programme's deputy director, Allison Mathis, commented that when the program started, "the idea of hand-held micro-drones was science fiction." but by the end of the program the technology had made drones, "a commercial reality as a child and hobbyist's toy flown by millions."[90] The Defense Advanced Research Projects Agency (DARPA) has a program called OFFensive Swarm-Enabled Tactics (OFFSET), which aims to continuously research, swarm technology and push their findings into practical

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[88] Yonah Jeremy Bob, "Exclusive: Israeli Technology Can Hack, Take Control and Stop Drone Swarm," *The Jerusalem Post*, March 9, 2021, https://www.jpost.com/israel-news/exclusive-d-fend-has-stopped-multiple-drone-swarm-attacks-661241.

[89] Zachary Kallenborn, "The Era of the Drone Swarm Is Coming, and We Need to Be Ready For It," *Modern War Institute at West Point* (blog), October 25, 2018, https://mwi.usma.edu/era-drone-swarm-coming-need-ready/.

[90] Merrin, *Digital War*, 328.

field applications.[91] Programs like these will continue to push the envelope of what AI-enabled swarms can accomplish as well as working on the problems of hardening the swarms from electronic and physical attacks.

AI is already playing a pivotal role for militaries in the sense domain. Militaries commanders use the operational function sense to provide them with knowledge.[92] This function encompasses all the activities from the collection of information to its processing, and ultimately providing a commander with actionable knowledge. The increasingly connected world we live in has created more and more data that can be analyzed. Recent conflicts in Afghanistan and Iraq quickly evolved past the conventional fight into insurgencies that persist to this day. In conventional fighting, the opponents are reasonably easy to identify once detected. A tank driving around in a conflict zone is a combatant and would be an acceptable target for engagement. In an insurgency, the insurgents look like everyone else, allowing them to hide without trying. The solutions is to use, "persistent collection in order to detect his presence"[93] This ranges from using human intelligence (HUMINT) to gather information by engaging with the local population, to monitoring close capture TV (CCTV), monitoring cell phone usage, recording aerial footage from drones, and many other sources of data.[94] AI has

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[91] DR. Timothy Chung, "OFFensive Swarm-Enabled Tactics (OFFSET)," *Defense Advanced Research Projects Agency > Our Research* (blog), accessed March 13, 2021, https://www.darpa.mil/program/offensive-swarm-enabled-tactics.

[92] "CFJP 3.0 - Operations," 1–5.

[93] Michael T. Flynn, Rich Juergens, and Thomas L. Cantrell, "Employing ISR SOF Best Practices," *JFQ* 50, no. 3 (2008): 56–57.

[94] Sarah Shoker, *Military-Age Males in Counterinsurgency and Drone Warfare*, 2021, 15.

applications in enabling the capture of the data, sifting through it to identify data of interest, establishing patterns and identifying targets.

This paper has already explored how AI can enable platforms like surveillance drones, which use automated image processing for navigation and AI control algorithms for flying the platform. The unique aspect of AI in the sense domain is how the subfields such as machine learning, machine vision and natural language processing can be used to identify patterns of interest and assign meaning to the troves of information that are generated by sensors, all without requiring human intervention.[95] This is a technology that has commercial and societal applications as well as military meaning that a country rich in commercial AI companies will also be reasonably expected to apply these same technologies to their military sense function. The ability to detect patterns from large troves of data does not require AI, humans are well suited to do it and have for decades. The American retail giant, Target, has been using statistics to analyze the buying patterns of their customers in order to categorize them and then use targeted advertising to increase sales. In 2002, the company assigned the task of identifying pregnant shoppers to a statistician working at the company. The statistician was able to use the pool of data that Target had amassed on the purchase history by customer, to identify 25 products that customers bought when pregnant. His analysis allowed the company to assign a

[95] Sarah Shoker, "How Artificial Intelligence Is Reshaping Global Power and Canadian Foreign Policy," *Opencanada.Org*, May 7, 2019, https://www.opencanada.org/features/how-artificial-intelligence-reshaping-global-power-and-canadian-foreign-policy/.

probability score that someone was pregnant as well as estimating the due date.[96] The rise of deep learning gives companies another analysis tool to automate the identification of these patterns. Facebook uses AI algorithms in natural language processing to identify potentially suicidal users of the platform. The algorithm can filter out hyperbolic use of terms such as, "I have so much homework I just want to die" as well as using indicators like what time of day someone posted and the comments that other people had left. Facebook then targets individuals it has flagged as being at risk of suicide with support options and in some cases alerting authorities to conduct wellness checks.[97]

Militaries similarly are capturing data at an incredible rate, necessitating the use of AI to sift through the data and highlight areas of interest for humans to verify. The ARGUS-IS is a 1.8 gigapixel camera that can be mounted on drones to conduct wide area surveillance. The camera captures 12 frames per second of an image covering 25 square kilometres with a resolution of 6 inches and capturing 1 exobyte of data per day.[98] The upgraded system was installed on MQ-9 Reaper in 2014 and captures a field of view covering 100 square kilometres along with software algorithms that identify moving objects in the image and creates a track of them. This allows analysts to search for objects or people of interest and view their physical history through an area over an extended

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[96] Charles Duhigg, "How Companies Learn Your Secrets," *The New York Times Magazine*, February 16, 2012, https://www.nytimes.com/2012/02/19/magazine/shopping-habits.html?pagewanted=1&_r=1&hp.

[97] Catherine Card, "How Facebook AI Helps Suicide Prevention," Press Release, *Facebook* (blog), September 10, 2018, https://about.fb.com/news/2018/09/inside-feed-suicide-prevention-and-ai/.

[98] Sebastian Anthony, "DARPA Shows off 1.8-Gigapizel Surveillance Drone, Can Spot a Terrorist from 20,000 Feet," *ExtremeTech*, January 28, 2013.

period of time.[99] The US Commanding General of its Army's Intelligence Centre noted that they lacked the capability to look at all the data that was being collected and required the analytics to automate this task.[100] One of the key differences between statistical analysis done by Target in the 2000s and modern analysis of imagery and voice is that the AI algorithms are able to categorize the raw data first and then perform analysis to find patterns. Analyzing 100 square km of imagery in 2002 would have taken a significant number of people to pore over the imagery, identifying structures of interest and personnel. The fact that the algorithms can automate that process is incredibly powerful on its on. The analytics that are then applied further demonstrate the power of AI.

In 2017 the US DoD established Project Maven "to augment or automate Processing, Exploitation, and Dissemination (PED) for tactical Unmanned Aerial System (UAS) and Mid-Altitude Full-Motion Video (FMV)."[101] As Project Maven progressed, the vision was expanded to merge publicly available information such as social media posts with classified information and became part of the DOD's Modernization

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[99] Stephen Trimble, "Sierra Nevada Fields ARGUS-IS Upgrade to Gorgon Stare Pod," *FlightGlobal*, July 1, 2014, https://www.flightglobal.com/civil-uavs/sierra-nevada-fields-argus-is-upgrade-to-gorgon-stare-pod/113676.article.

[100] Sandra Jontz, "With IC 'Swimming in Sensors and Drowning in Data,' Analyst Seek Big Data Solutions," *Signal*, April 14, 2015, https://www.afcea.org/content/?q=Article-ic-swimming-sensors-and-drowning-data-analysts-seek-big-data-solutions.

[101] Deputy Secrety of Defencse to Various U.S. Agencies, "Estalishment of Algorithmic Warfare Cross-Functional Team (Project Maven)" (Department of Defence, April 26, 2017), https://www.govexec.com/media/gbc/docs/pdfs_edit/establishment_of_the_awcft_project_maven.pdf.

Strategy.[102] The next stage in AI development in the Sense realm is using it to predict activity before it happens by learning from the big data sets that have been generated to date. Research is already underway into this type of prediction though it remains to be seen how accurate and powerful it will turn out to be.[103] Online retailer Amazon patented a technology for predicting what consumers would buy and shipping it before it was ordered in 2013.[104] Amazon has not been publishing their prediction algorithms so it is not clear to what extent the company has implemented this technology.

The third operational function to be enabled by AI is Sustain or the "ability to maintain effective military power to achieve the desired effects."[105] The sustain function is one of the most advanced AI functions due to its overlap with the field of commercial logistics. Commercial vehicle fleets benefit from improved operational availability and lowered maintenance costs the same as a military fleet. Supply chain management is critical for massive internet retailers like Amazon, similar to a military supply system. A car crash victim will benefit from similar medical advancements as a soldier injured in combat. The financial benefits for commercial companies will continue to push advances in this field and these advances will then have application for military's logistics services.

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[102] Richard H. Shultz and General Richard D. Clarke, "Big Data At War: Special Operations Forces, Project Maven, and Twenty-First-Century Warfare," *Modern Ware Institute*, accessed March 15, 2021, https://mwi.usma.edu/big-data-at-war-special-operations-forces-project-maven-and-twenty-first-century-warfare/.

[103] M Irfan Uddin et al., "Prediction of Future Terrorist Activities Using Deep Neural Networks," ed. Dimitrios Stamovlasis, *Complexity* 2020 (2020): 16, https://doi.org/10.1155/2020/1373087.

[104] Connor Simpson, "Amazon Will Sell You Things Before You Know You Want to Buy Them," *The Atlantic*, January 20, 2014, https://www.theatlantic.com/technology/archive/2014/01/amazon-thinks-it-can-predict-your-future/357188/.

[105] "CFJP 3.0 - Operations," 1–5.

In the transportation realm, AI offers the possibility of autonomous convoys, which can follow a human leader in order to drastically increase the amount of supplies one person, can transport.[106] DARPA is currently funding research in off-road autonomous driving.[107] Commercial transportation services run in North America typically run on paved, marked surfaces, which are well defined by highly detailed maps and satellite imagery. This makes autonomous driving for commercial vehicles a 2-dimensional problem with a relatively small variety of expected obstacle classes. Military transportation must contend with a variety of roadways and surfaces, which range from well-marked highways to crossing open, unmarked, and rough terrain. The off-road environment is not typically well defined with high definition imagery and the number of obstacle types is relatively larger.[108] The complexity of the off-road problem means that autonomous convoys for the military will lag behind the commercial sector, though AI technology will be the key to realizing this. Semi-autonomous vehicles may bridge the gap in convoy scenarios where a human lead is followed by one or more semi-autonomous vehicles.

The field of equipment maintenance will also see advancements with the inclusion of AI monitoring systems, which can monitor equipment for health, identifying

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[106] Scharre, *Army of None*, 59.

[107] "Robotic Autnonomy in Complex Environments with Resiliency - Simulation," Grant Opportunity (Arlington, VA: DARPA - Tactical Technology Office, November 30, 2020), https://www.grants.gov/web/grants/view-opportunity.html?oppId=330584.

[108] "Robotic Autnonomy in Complex Environments with Resiliency - Simulation," 4.

components, or systems that will fail.[109] Aircraft have used health-and-usage-monitoring systems (HUMS) for decades due to the impact of systems failing in flight.[110] This allows for repair work to be performed on an as-required basis rather than conducting preventive maintenance or corrective maintenance. Preventative maintenance can be inefficient as components are replaced based on estimated lifespan rather than their actual condition. Corrective maintenance is also inefficient as a piece of equipment may need to be recovered from its point of failure to a suitable repair location and the complexity of the repair can increase due to further damage caused by the failed component. The use of machine learning has the potential to increase the accuracy of HUMS diagnostics, an increasingly important feature as land-based vehicles become increasing complex.[111] Commercial examples of AI HUMS include Acerta, based in Waterloo, ON. The company claims to have trained their neural network based on sensor readings during normal operation and could then predict an impending engine failure 400 km prior to its occurrence.[112] HUMS is another example of a well established technology that is improved with the implementation of modern AI algorithms.

Manufacturing is another field that may be transformed by automation, enabled by machine learning. The addition of computer vision, touch and ability to optimize data

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[109] E. Rabeno and M. Bounds, "Condition Based Maintenance of Military Ground Vehicles," in *2009 IEEE Aerospace Conference*, 2009, 1, https://doi.org/10.1109/AERO.2009.4839683.

[110] Sreeja Rajesh and Benjamin Francis, "A Study of Condition Based Maintenance for Land Force Vehicles" (Edinburgh, South Australia: Land Operations Division, Defense Science and Technology Organisation, 2012), iii.

[111] Rajesh and Francis, 1.

[112] "On-Road Failure Prediction," Acerta, n.d., https://acerta.ai/case-studies/on-road-failure-prediction/.

will improve robotic manufacturing, reducing the reliance on human workers.[113] It is estimated that the use of robots in manufacturing will rise to 25% of manufacturing tasks by 2025.[114] The ability to rapidly manufacture a wide range of supplies would enable a military to decrease their required warehousing and stocks and use predictive algorithms to anticipate demand. This can result in lower procurement costs, lower warehousing costs, and enable the move of manufacturing jobs back to modern countries who traditionally have not been able to cost-effectively manufacture many goods due to the high cost of labor. DARPA funded a competition in 2012 for an automated textile manufacturing capacity, which could transfer some of the $100B worth of textiles the US imports every year, back to American manufacturers.[115]

There are many other applications of AI to militaries, which are already changing how business is done and will continue doing so as the field progresses. Cyber warfare is a new and fast growing field of combat with much of the activity occurring just below the threshold of war. AI can be used in cyberattacks, cyber security and defense and increases the complexity of attacks.[116] Complete command by AI is seemingly far-fetched science fiction fare at present, though it has been promised for some time now. US Secretary of Defense Robert Work quoted Russian General Gerasimov, "[Gerasimov]

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[113] Kai-Fu Lee, *AI Superpowers: China, Silicon Valley, and the New World Order* (Boston: Houghton Mifflin Harcourt, 2018), 121.

[114] Mark Prigg, "Will Robots Take YOUR Job? Study Says Machines Will Do 25% of US Jobs That Can Be Automated by 2025," *Daily Mail*, February 9, 2015, https://www.dailymail.co.uk/sciencetech/article-2946704/Cheaper-robots-replace-factory-workers-study.html.

[115] Del Monte, *Genius Weapons*, 29.

[116] Daniel Ventre, *Artificial Intelligence, Cybersecurity and Cyber Defense* (Hoboken: ISTE Ltd / John Wiley and Sons Inc, 2020), 156–57.

said, and I quote, 'In the near future, it is possible that a complete roboticized unit will be created capable of independently conducting military operations,'"[117] Many of the AI applications that pertain to the operational functions of Act and Sense will also be applicable to the Shield operational function. Autonomous defensive systems like the US AEGIS are designed to act faster than humans can, protecting assets that would otherwise be lost. The intelligence functions used in Sense, provide information and knowledge that will help defend militaries as well as enable offensive action.

The current military applications of AI are still narrow in nature. A variety of narrow AI systems can be integrated to make intelligent platforms but these systems are still operating at capacities far from general human intelligence. For now, humans will be an integral part of nations military, augmented by AI systems, to improve their performance. Humans are necessary to protect against edge cases, situations that occur far outside of the scope of normal, for which an AI algorithm may have no context to make a reasonable decision. Systems like AlphaZero which train themselves to play and master a game are demonstrative of the rapidly progressing field of AI and hint at future power for military applications.[118] The issue is that AlphaZero is heavily bounded to playing two-player games and will not command a military unit or drive a tank.[119] It remains to be seen if AI can operate as expertly in the mess of the real world, once it is

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[117] Danielle Muoio, "Russia and China Are Building Highly Autonomous Killer Robots," *Business Insider*, December 15, 2015, https://www.businessinsider.com/russia-and-china-are-building-highly-autonomous-killer-robots-2015-12?op=1.

[118] Yvonne Masakowski, ed., *Artificial Intelligence and Global Security: Future Trends, Threats and Considerations*, First edition (Bingley, UK: Emerald Publishing Limited, 2020), 214.

[119] Stuart J. Russell, *Human Compatible: Artificial Intelligence and the Problem of Control* (New York? Viking, 2019), 48.

taken out of the clean bounds of simulations and rules based games. It is possible that the advances to date in deep learning will reach a fundamental limit and stall, much like AI's expert systems did in the 1980s. Many of the world's powers believe AI has the capacity to continue improving and they are all racing to be the leaders in AI. The next chapter will examine the leading contenders in the field of military AI and assess whether there is a possibility of another nation using AI to overtake the US as the World's most powerful military.

CHAPTER 4 – AI POWER

Many nations and technology researchers have bought into the theory that AI will be the key to global dominance.[120] These theories may be hyperbolic but they exaggerate to make the point that AI will increase a nations' relative power in a significant way. AI may be a pivotal technology that brings about a new industrial revolution, much like the steam engine did.[121] World leaders have made public proclamations about the importance of AI, and the major players in the world order have all developed AI strategies, seeking to propel their country towards and AI imbued future. The previous chapter discussed the multitude of AI applications to militaries, but AI is a cross-domain technology. Every element of a nations power can be affected and improved with the implementation of AI to the existing technologies, and possibility of new technologies built around it. This chapter will seek to explore the relative potential of the United States, China and Russia, to adopt AI and become the leader in the technology. The United States was chosen, as it is the current leading power within the world. Russia and China were chosen to contrast with the United States as they have both played significant roles in challenging American dominance. By comparing the current standing of each country, and assessing their potential for improvement, the chapter will seek to determine if Russia or China has the capacity to overtake the United States' military in terms of power.

A country with a military, empowered by AI, will also have AI as a key component of their overall national strategy. A national strategy will coordinate the

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[120] Masakowski, *Artificial Intelligence and Global Security*, 28.

[121] Paul Scharre, Michael C. Horowitz, and Robert O. Work, "Artificial Intelligence What Every Policymaker Needs to Know," 3.

relevant actors within a nation to act with reference to the framework developed by that state. It ensures a more efficient use of the resources within the country by aligning what might otherwise be a scattered approach.[122] Between 2015 and 2019, at least 36 strategies were adopted by a variety of countries with Russia publishing its in only 2019.[123] The majority of the national AI Strategies are written based on forwarding economic progress for the nations.[124] A willingness to adopt AI technology for military applications is clearly required to diffuse AI technology from commercial sectors to defence. It is therefore important when considering a country's AI strategy to examine the ethical uses of AI that they pursue or deny. The Western World may be at a military disadvantage when it comes to AI as it faces more ethical and moral constraints than its adversaries.[125]

The Chinese Strategy published in 2017 is aimed at rapidly increasing its uptake in AI technology, matching pace with the remainder of the world by 2020 and to be the world leader in AI by 2030.[126] While not the first Chinese strategy to incorporate AI, this document was the first to focus on AI as a unified strategy.[127] In the strategy, China acknowledges that the "overall level of development of China's artificial intelligence and

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[122] Ventre, *Artificial Intelligence, Cybersecurity and Cyber Defense*, 86.

[123] Ventre, 86–89; Nikolai Markotkin and Elena Chernenko, "Developing Artificial Intelligence in Russia: Objectives and Reality," Commentary, May 8, 2020, https://carnegie.ru/commentary/82422.

[124] Ventre, *Artificial Intelligence, Cybersecurity and Cyber Defense*, 89.

[125] Masakowski, *Artificial Intelligence and Global Security*, 25.

[126] Chinese State Council, "A New Generation of Artificial Intelligence Development Plan"; Pablo Robles, "China Plans to Be a World Leader in Artificial Intelligence by 2030," *South China Morning Post*, October 1, 2018, https://multimedia.scmp.com/news/china/article/2166148/china-2025-artificial-intelligence/index.html.

[127] Huw Roberts et al., "The Chinese Approach to Artificial Intelligence: An Analysis of Policy, Ethics, and Regulation," *AI & Society* 36, no. 1 (March 2021): 59–77, https://doi.org/10.1007/s00146-020-00992-2.

that of the developed countries still have gaps."[128] During a Chinese Politburo study session on AI the country's president, Xi Jinping pressed that China must "pay firm attention to the structure of our shortcomings, ensure that critical and core AI technologies are firmly grasped in our own hands."[129] The Chinese strategy further promotes quickly embedding AI technology into the field of national defense innovation.[130] China's strategy also involved naming national champions, companies selected to develop specific areas of AI in exchange for incentives, which would help them, dominate their respective sectors.[131] When it comes to China's ethical boundaries on AI, they have sent mixed signals. They have expressed concerns with an AI arms race in their national strategy and proposed a worldwide ban on LAWS, but they have continued investment and development of LAWS and their UN position paper defined LAWS in a way that does not match any international norms.[132] In their position paper

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[128] Chinese State Council, "A New Generation of Artificial Intelligence Development Plan."

[129] Gregory C. Allen, "Understanding China's AI Strategy," White Paper (Center for a New American Security, February 6, 2019), https://www.cnas.org/publications/reports/understanding-chinas-ai-strategy; Elsa Kania and Rogier Creemers, "Xi Jinping Calls for 'Healthy Development' of AI (Translation)," *Cybersecurity Inititiave* (blog), accessed March 17, 2021, https://www.newamerica.org/cybersecurity-initiative/digichina/blog/xi-jinping-calls-for-healthy-development-of-ai-translation/.

[130] Chinese State Council, "A New Generation of Artificial Intelligence Development Plan," 21.

[131] Roberts et al., "The Chinese Approach to Artificial Intelligence: An Analysis of Policy, Ethics, and Regulation," 61; Meng Jing and Sarah Dai, "China Recruits Baidu, Alibaba and Tencent to AI 'National Team,'" South China Morning Post (Online) (Hong Kong: South China Morning Post Publishers Limited, November 21, 2017), 1969092031, ProQuest Central, https://search.proquest.com/blogs,-podcasts,-websites/china-recruits-baidu-alibaba-tencent-ai-national/docview/1969092031/se-2?accountid=9867.

[132] Gregory C. Allen, "Understanding China's AI Strategy"; People's Republic of China, "Position Paper Submitted at 'Group of Governmental Experts of the High Contracting Parties to the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May Be Deemed to Be Excessively Injurious or to

they include five basic characteristics of LAWS including, "indiscriminate effect, meaning the device will execute the task of killing and maiming regardless of conditions, scenarios and targets."[133] It is obvious that LAWS with indiscriminate effect should be banned but by only proposing a ban LAWS that kill indiscrimanetly, China is allowing itself a significant amount of freedom in what its LAWS may do. It appears that China is attempting to showcase a veneer of adopting ethical norms and standards that apply to AI while working to give themselves the leeway to develop the technology on terms that suit them. China appears to be legitimately posturing itself to overtake the United States as a world superpower and clearly sees AI as being an important component of this strategy. Their national AI strategy recognizes the importance of the academic and commercial sectors' roles in developing AI and they also recognize the advantage AI will bring to their defence forces. China has developed a credible and coherent AI strategy while not outwardly constraining themselves by ethical boundaries. This does not suggest that they do not consider ethical, moral, and safety concerns in their AI development but instead that they do not deem it in their interests to outwardly take a stance on this considerations at this time.

Virtually any book, paper or article about Russian AI will include Russian President, Vladimir Putin's famed quote "The one who becomes the leader in [AI] will be

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Have Indiscriminate Effects,'" April 11, 2018, https://undocs.org/CCW/GGE.1/2018/WP.7.

[133] People's Republic of China, "Position Paper Submitted at 'Group of Governmental Experts of the High Contracting Parties to the Convention on Prohibitions or Restrictions on the Use of Certain Conventional Weapons Which May Be Deemed to Be Excessively Injurious or to Have Indiscriminate Effects,'" 1.

the ruler of the world".[134] Russia was a relatively late-comer to adopting a national AI strategy with *Decree of the President of the Russian Federation on the Development of Artificial Intelligence in the Russian Federation* only coming out in October 2019.[135] The Russian strategy focuses on using AI to boost its economy and neglects prioritization of AI defence applications.[136] One of the key players in driving their strategy was the president of Russian state-owned bank Skerbank, further emphasizing that economic gain is the driver of the strategy.[137] Large datasets are one of the key enablers to deep learning and the Russian strategy prioritizes access to these datasets, though focusing on government access to public data as opposed to the US policy of opening up government data to the public.[138] Russia has pushed back on international efforts to enact bans on LAWS claiming that as there are no current examples of LAWS they can not come to any consensus.[139] Russia has essentially refused to define LAWS and will not accept any of the definitions that currently exist. Actions like this back up fears that Russia may prioritize the advantage of AI-equipped weapons over ethical and moral qualms about

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[134] Michael Dahm, "Chinese Debates on the Military Utility of Artificial Intelligence," June 5, 2020, https://warontherocks.com/2020/06/chinese-debates-on-the-military-utility-of-artificial-intelligence/; Russell, *Human Compatible*, 144; Del Monte, *Genius Weapons*, 185; Merrin, *Digital War*, 344.

[135] "Translation Decree of the President of the Russian Federation on the Development of Artificial Intelligence in the Russian Federation," October 28, 2019, https://cset.georgetown.edu/research/decree-of-the-president-of-the-russian-federation-on-the-development-of-artificial-intelligence-in-the-russian-federation/.

[136] Margarita Konaev, "Thoughts on Russia's AI Strategy," *CSET*, October 20, 2019, https://cset.georgetown.edu/article/thoughts-on-russias-ai-strategy/.

[137] Nikolai Markotkin and Elena Chernenko, "Developing Artificial Intelligence in Russia: Objectives and Reality."

[138] Margarita Konaev, "Thoughts on Russia's AI Strategy."

[139] "Examination of Various Dimensions of Emerging Technologies in the Area of Lethal Autonomous Weapons Systems, in the Context of the Objectives and Purposes of the Convention" (Geneva, November 13, 2017), https://admin.govexec.com/media/russia.pdf.

their usage.[140] Russia's late strategy suggests that it may not have initially believed in the value of AI and were waiting for the technology to mature before invoking a plan for adoption. Vladimir Putin's comments on the power of AI and his late strategy suggest he acknowledges that Russia will never be a leader in the field and instead have chosen to be fast followers. The speed of AI research followed by commercial application means that AI can procured commercially instead of developed internally. The official focus on economic gain from their AI strategy further reinforces this possibility. A realistic possibility exists that Russian official AI strategy has purposefully omitted military applications and a separate internal strategy exists to guide the developments in the military realm. Russian websites specialized in defence and political issues have developed thoughts on military use of AI that reflects Russian thought on the subject.[141]

The US strategy on AI is contained within its third national offset strategy. Announced in 2014 by Secretary of State Chuck Hagel, the Third Offset Strategy is designed to "ensure that America's power-projection capabilities continue to sustain our competitive advantage over the coming decades."[142] The strategy is to pursue cutting edge technologies and systems such as autonomous systems, robotics and big data. The US hopes that by pursuing this offset strategy it not only maintains the capability to defeat any foe but also deter any attempts.[143] The US is highly aware of its China and Russia's counter-network capabilities and seeks to exploit AI and autonomy to strengthen

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[140] Del Monte, *Genius Weapons*, 88.

[141] Ventre, *Artificial Intelligence, Cybersecurity and Cyber Defense*, 133.

[142] Secretary of Defense Chuck Hagel, "Reagan National Defense Forum Keynote," November 15, 2014, https://www.defense.gov/Newsroom/Speeches/Speech/Article/606635/.

[143] Del Monte, *Genius Weapons*, 64.

its conventional deterrence.[144] The US has published several AI initiatives and strategy papers since the launch of its third offset strategy. In *Preparing for the Future of Artificial Intelligence*, published in 2016, the American position on LAWS is laid out, confirming they will only be developed in accordance with international humanitarian law.[145] The 2019 update to the National AI R&D strategic plan included sub-strategies focusing on addressing ethical, legal and societal implications of AI along with ensuring the safety and security of AI systems.[146] The US DOD policy on LAWS, DOD 3000.09 also reinforces the national policy requiring that "autonomous and semi-autonomous weapon systems shall be designed to allow commanders and operators to exercise appropriate levels of human judgement" and that their use must be "in accordance with the law of war,…, and applicable rules of engagement".[147] The early adoption of a an overall technological strategy suggests that the Americans are hedging their bets on virtually all technologies as being potential threats to their defence capabilities and therefore they are investing in them all. The further refinement of AI strategies shows that they have become certain of the importance of AI and must dominate the field in order to maintain a technological overmatch in it. Their inclusion of ethical principals on

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[144] Cheryl Pellerin, "Deputy Secretary: Third Offset Strategy Bolsters America's Military Deterrence," *DOD News*, October 31, 2016, https://www.defense.gov/Explore/News/Article/Article/991434/deputy-secretary-third-offset-strategy-bolsters-americas-military-deterrence/.

[145] "Preparing for the Future of Artificial Intelligence" (Executive Office of the President National Science and Technology Council Committee on Technology, October 2016), 3, https://obamawhitehouse.archives.gov/sites/default/files/whitehouse_files/microsites/ostp/NSTC/preparing_for_the_future_of_ai.pdf.

[146] Select Committee on Artificial Intelligence, "The National Artificial INtelligence Research and Development Strategic Plan: 2019 Update" (National Science & Technology Council, June 2019), 19–26, https://www.nitrd.gov/pubs/National-AI-RD-Strategy-2019.pdf.

[147] "Directive 3000.09 - Autonomy in Weapon Systems," 2–3.

LAWS is in line with Western sentiments and is critical for maintaining public trust as well as leaving collaboration options opens with commercial ventures. The importance of maintaining Western values was demonstrated when Google was forced to not renew its contract to develop AI for the US DoD over employees' objections.[148]

In order for a national strategy to be relevant, a country needs the resources available to be corralled and directed. The primary resource required is funding with which grants can be applied, research programs can be funded and technologies can be procured. National policies that support AI will require spending that may cut into other national strategies so a country with limited funding will not be able to make the investments required for AI.[149]

China reportedly budgeted $175B for defence spending in 2019, second only the US who spends roughly triple that amount.[150] In 2018 global equity funding of AI start-ups, 48 percent of funding came from China compared to 38 percent from the United

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[148] ew Harwell, "Google to Drop Pentagon AI Contract after Employee Objections to the 'Business of War': Google Has Faced Widespread Public Backlash and Employee Resignations for Helping Develop Technological Tools That Could Aid in Warfighting.," *Washington Post – Blogs* (blog) (Washington: WP Company LLC d/b/a The Washington Post, June 1, 2018), 2048362786, ProQuest Central, https://search.proquest.com/blogs-podcasts-websites/google-drop-pentagon-ai-contract-after-employee/docview/2048362786/se-2?accountid=9867.

[149] Ventre, *Artificial Intelligence, Cybersecurity and Cyber Defense*, 95.

[150] Minnie Chan and Zhen Liu, "Modern Military Still a Top Priority as China Boosts Defence Spending," *South China Morning Post*, March 6, 2019, 2216972335, ProQuest Central, https://search.proquest.com/newspapers/modern-military-still-top-priority-as-china/docview/2216972335/se-2?accountid=9867.

States.[151] China therefore aims to use AI to leapfrog the US, focusing on US weaknesses rather than matching its strengths.[152] They have focused on cyber warfare targeting US military reliance on networks.[153] The Chinese have also leveraged industrial espionage for decades and while promising to end this practice against US commercial companies, may continue using this as a partial means for acquiring further AI technologies.[154] In addition to the financial resources that China spends on AI, it is home to some of the world leading AI companies within AI subcategories. SenseTime and DJI have vast market leads in computer vision and consumer drones respectively with steady growth year after year.[155] Chinese universities have been conducting research on AI for the last 50 years with 15 universities recording AI research programs between 1970 and 1980.[156] China believes it is a near-peer or equivalent to the US in terms of AI technology. At a 2018 conference it was claimed that China was the top in the world for total AI research papers and number two for number of AI companies.[157] The claims of top performance must be taken into context though as half of the papers were authored by multinational research teams and the drone company DJI develops all of its software in Palo Alto,

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[151] Pablo Robles, "China Plans to Be a World Leader in Artificial Intelligence by 2030."

[152] Roberts et al., "The Chinese Approach to Artificial Intelligence: An Analysis of Policy, Ethics, and Regulation," 62.

[153] Elsa B. Kania, "Battlefield Singularity: Artificial Intelligence, Military Revolution, and China's Future Military Power" (Washington, DC: Center for a New American Security, November 2017), 27–28.

[154] Elsa B. Kania, 40; Del Monte, *Genius Weapons*, 87.

[155] Gregory C. Allen, "Understanding China's AI Strategy."

[156] Ventre, *Artificial Intelligence, Cybersecurity and Cyber Defense*, 15.

[157] "China AI Development Report 2018" (China Institute for Science and Technology Policy at Tsinghua University, July 2018), 13,38, http://www.sppm.tsinghua.edu.cn/eWebEditor/UploadFile/China_AI_development_report_2018.pdf.

California.[158] China's considerable resources in terms of funds, personnel and institutions all make it a contender for world dominance in the field of AI. Irrespective of whether it has overtaken the US yet, its steady strides in the field of AI show an accelerating uptake that will make it a military and commercial competitor with the US.

Russia is at a clear disadvantage in terms of resources compared to China and the United States. Their 2020 population was estimated at 141.7 million compared to China's 1.4 billion and the United States' 335 million.[159] Similarly their estimated 2019 GDP at purchasing power parity was $4.0 trillion compared to $22.5 trillion for China and $20.5 trillion for the US.[160] Russia was also fourth in world spending on defence in 2019 with $65.1 billion compared to $175 billion for China and $732 billion for the United States. Russia's interest in AI research began in the early 1960s and the city of Akademgorodok was built in Siberia in 1965 for science research. This city became the hub of AI research in Russia and is one of the high-tech centres in Russia now.[161] Despite their early start, the Russians lagged behind the US in terms of AI research and are now not considered as having the capacity to ever lead in AI research, commercial companies, or overall military application as compared to the US and China. Russia will likely use their AI resources to strategically target certain sub-fields within AI to excel at such as cyber warfare rather than trying to compete across the full domain of AI capability. Their national strategy implies that they will seek to enhance their economy first with AI rather

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[158] Gregory C. Allen, "Understanding China's AI Strategy."

[159] *The World Factbook* (CIA), accessed March 18, 2021, https://www.cia.gov/the-world-factbook/.

[160] *The World Factbook*.

[161] Merrin, *Digital War*, 17.

than focusing on defence though they may have deliberately not published their plans for AI within a military context.

The US is currently in a position of strength when it comes to resources to support AI initiatives. While the US has a quarter of the Chinese population and a GDP slightly less, they spend significantly more on defence and have a wealth of institutions that support the AI economy. In 2020 the US had 2, 130 active AI firms that had received more than $1 million in funding compared to 398 for China, and in 2019 had funded AI venture capital and private equity $14.3 billion compared to $5.6 billion for China. According to a Chinese produced AI Development report, in 2018 China and the US each had 7 of the top 20 institutions in terms of AI paper output.[162] The US has the top two companies in the world in terms of AI patent holdings (IBM and Microsoft) and holds the largest amount of worldwide AI talent at 13.9% of total compared to China's 8.9%.[163] The talent pool consists of researchers working in the field of AI who have received a patent or written a paper related to AI over the last decade. The widely touted AI company DeepMind, creater of AlphaGo and AlphaZero is also owned by Google, another top AI company based in the US.[164] The US clearly has the dominant position in terms of resources to support its AI strategy and, if sufficiently determined, will be able to engage in an all out AI arms race with the Chinese.

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[162] "China AI Development Report 2018," 16.
[163] "China AI Development Report 2018," 28,34.
[164] Lee, *AI Superpowers*, 122.

A country with the resources and strategy to direct them will be on the course to have an effective implementation of AI within their military. All things being considered equal, each countries current state of AI and the rate that they are moving forward will determine at which point in the future they surpass or are passed by another country. The US is considered the world leader in AI at present due to the years of investment, research and commercial development they have had in the field.[165] China has been rapidly modernizing over the last half century and believes that it has the potential to match the US economically within the next three decades.[166] In terms of AI, some claim that China is already edging out the United States and will clearly lead the field in the next five years.[167] While Russia acknowledges the relative importance of AI, it does not have the same potential to lead in the field but with continued progress will still be an influential and powerful player. They may lead in certain areas of AI progress and the US and China will need to always consider their influence.[168]

China has been investing in AI technologies in a number of fields including autonomous stealth drones, domestic surveillance applications, and intelligentization (cognitive-centric warfare). Chinese military strategy seeks to use AI as it attacks its adversary's system-of-systems. This strategy seeks to use its kinetic and not-kinetic forces to overwhelm the information systems and then pick off the isolated elements of

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[165] Daniel Castro, Michael McLaughlin, and Eline Chivot, "Who Is Winning the AI Race: China, the EU or the United States?" (Centre for Data Innovation, August 2019).

[166] David Dollar, Yiping Huang, and Yang Yao, eds., *China 2049: Economic Challenges of a Rising Global Power* (Washington, D.C: Brookings Institution Press, 2020), 35.

[167] Lee, *AI Superpowers*, 120.

[168] Nikolai Markotkin and Elena Chernenko, "Developing Artificial Intelligence in Russia: Objectives and Reality."

its adversary.[169] Russia has been the focus of concern for its influence activities over the last several years. A 2021 report by the US Intelligence Community assessed that Russian President Vladimir Putin had authorized influence activities aimed at the US 2020 Presidential Election.[170] While their influence campaigns may have only used simple AI bots, they have had an impact, which will only increase as they further develop their capability.[171] Russia has also been able to test out its AI military tech in Syria using both airborne and underwater AI equipped drones.[172] The US has been investing in a vast number of AI technologies to empower their military over the last decade and beyond. Over the last two decades the US has focused much of their efforts on improving autonomy of air, ground, sea and sub-sea vehicles with newer work looking at autonomous swarms.[173] More recent work as discussed earlier has focused on intelligence and reconnaissance AI.

It is clear that the US, China and Russia are all pursing AI for both economic and defence reasons. There is an AI arms race going on and with that the danger that nations feel the need to build autonomous weapons so as not to be left behind.[174] China's relative strength in the field of AI poses a credible threat to US military superiority. As their

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[169] Dahm, "Chinese Debates on the Military Utility of Artificial Intelligence."

[170] "Foreign Threats to the 2020 US Federal Election," Intelligence Community Assessment (National Intelligence Council, March 10, 2021), i, https://www.dni.gov/files/ODNI/documents/assessments/ICA-declass-16MAR21.pdf.

[171] Jill Dougherty and Molly Jay, "Russia Tries to Get Smart about Artificial Intelligence.(Spring 2018)," *The Wilson Quarterly (Washington)* 42, no. 2 (2018): 1,3.

[172] Dougherty and Jay, 4.

[173] Scharre, *Army of None*, 15.

[174] Scharre, 117.

momentum increases, it stands a real chance of gaining a decisive AI overmatch over the world, giving them the chance to be the dominant military power.

CHAPTER 5 – AI ISSUES

Advances in AI over the last decade have been celebrated with fanfare and hype brought about by impressive performances. This hype has created a mythos around AI and many pundits tout with certainty the future progress that AI systems will make. The result is often disillusionment as "overpromised" AI ends up "underdelivering".[175] This creates the conditions for an AI winter where commercial interests wane and research funding is diverted to other fields.[176] This chapter will seek to examine some of the issues and blockades that must be faced for militaries to fully adopt AI.

A fundamental vulnerability in the algorithms used for AI would threaten its utility in military applications, especially one that is widely known within AI circles. One such vulnerability was discovered by AI researchers attempting to design an AI algorithm that could creatively generate new images. The researchers input images into the system and then had it create new images that were intended to be the same type of image. The results were distorted pixels that were unrecognizable to humans but that AI image recognition misclassified while indicating that it had high confidence in its classification.[177] Images created to confuse AI image recognition algorithms are known as adversarial images. Further research has continued looking at both offensive and defensive cases for adversarial images, though offensive research has been fruitful in the

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[175] Masakowski, *Artificial Intelligence and Global Security*, 25.

[176] Thomas H. Davenport, *The AI Advantage: How to Put the Artificial Intelligence Revolution to Work*, Management on the Cutting Edge (Cambridge, MA: The MIT Press, 2018), 10.

[177] Scharre, *Army of None*, 182.

initial term.[178] Practical research into attacks in the real world have shown success fooling image recognition using adversarial printed pictures, stickers placed over traffic signs which would not garner notice from a human but fooled computer vision, and 3D printed adversarial objects.[179] Other examples have taken the adversarial attacks from the realm of images to audio recognition and text based AI systems.[180] Research has also continued into defensive systems, finding novel ways to detect images that have been altered and to create robust algorithms that are less susceptible to attacks.[181]. The research into defenses against adversarial images shows that while vulnerability exists, it can be countered and protected against. Both the field of deep learning and the narrower field of research into adversarial images are relatively new. AI research has been ongoing for decades, changing dramatically over time as new algorithms, computational power, and large datasets have transformed the field. Deep learning may be the current leader in AI algorithms but that may change in the future as new algorithms are developed. Adversarial images are not the Achilles heel of AI but rather a warning that AI systems will have vulnerabilities just like any other physical or virtual system. Military applications will need to be developed with a critical approach to protecting against vulnerability.

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[178] Russell and Norvig, *Artificial Intelligence*, 21.5.1.

[179] Naveed Akhtar and Ajmal Mian, "Threat of Adversarial Attacks on Deep Learning in Computer Vision: A Survey," *IEEE Access* 6, no. Journal Article (2018): 14418–20, https://doi.org/10.1109/ACCESS.2018.2807385.

[180] Scharre, *Army of None*, 184.

[181] Tao Yu et al., "A New Defense Against Adversarial Images: Turning a Weakness into a Strength," in *Advances in Neural Information Processing Systems 32 (NeurIPS 2019)* (33rd Conference on Neural Information Processing Systems (NeurIPS 2019), Vancouver, Canada, 2019).

A common concern regarding AI systems is that their design is so complex that humans cannot explain why an output was produced for a particular input. The common nomenclature for this is to call the system a black box, as if an input is put into the black box and it produces an output, but no observation can be conducted within the box.[182] This is clearly a concern for military applications where a system may be used to take a life or contribute to the decision making cycle which leads to offensive action. Soldiers may wonder if they could be charged after listening to an AI system's recommendation only to turn out that the system was horrifically wrong.[183] Like the adversarial images example, even if an AI algorithm designer has a good grasp of their system, what weakness might the AI have that can not be anticipated.[184] A further problem is introduced by the AI arms race, highlighted by Putin's prognosis of the AI ruler being the world ruler. If this is true than the focus is on achieving capability as quickly as possible rather than control.[185] If a nation is concerned that they will fall behind as other nations increase their productivity and gain new capabilities, this may lead to more black box AI systems. Issues like these have give rise to overall ethical concerns with AI systems being used in military applications. A group that claims to be comprised of 4500 experts and 170+ non government organizations have signed on to the Campaign to Stop Killer Robots. The group outlines the ethical issues with fully autonomous weapons and urges a full ban on their development, production and use.[186] Real world examples of AI systems horrifically and unexpectedly malfunctioning exist. In 2010 an automated algorithm used

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[182] Russell and Norvig, *Artificial Intelligence*, 19.9.4.
[183] Masakowski, *Artificial Intelligence and Global Security*, 33.
[184] Scharre, *Army of None*, 189.
[185] Russell, *Human Compatible*, 144.
[186] "The Threat of Fully Autonomous Weapons," *Campaign to Stop Killer Robots* (blog), accessed April 26, 2021, https://www.stopkillerrobots.org/learn/#problem.

for financial trading rapidly conducted a series of trades, which erased nearly $1 trillion from global markets in the space of minutes.[187] Arguments against the development of fully autonomous weapons neglect to account for nations like Russia or China, which many accept a higher risk tolerance in their AI weapons development as an expense in order to gain from the increased advantage that comes from these systems. The Campaign to Stop Killer Robots realizes and acknowledges that these adversarial nations are developing LAWS. The argument against their development is already lost as engineers continue designing and building new systems. The ethical issues of the AI black box is not an impediment to military applications of AI. The government strategies and associated funding are in place. The black box is a challenge, which must be addressed through the careful applications of these strategies and application of government funds. Governments must promote and fund "the safe and responsible development of [Machine Learning] ML technology" in order to address the "areas where the private sector is not clearly incentivized to invest."[188] The fundamental complexity of AI algorithms may mean that there is always a residual risk resident in a system. Guidelines must be established to mitigate these risks to the greatest extent possible and policy makers must ultimately establish the level of risk they are willing to accept. Protocols, procedures and laws will need to be established to enable soldiers to use AI weapons without fear of repercussion if the weapon fails. Unambiguous delegation of responsibility will ensure

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[187] "Findings Regarding the Market Events of May 6, 2010" (U.S. Commodity Futures Trading Commission, U.S. Securities & Exchange Commission, September 1, 2010), 39.

[188] William A. Carter and Emma Kinnucan, "A National Machine Intelligence Strategy for the United States," *Policy File* (Center for Strategic and International Studies, 2018), 18

that designers, policy makers and military practitioners can all fulfill their role in the AI weapon system while maximizing their accountability.

Much of the writing regarding the future of AI and warfare make fanciful predictions or refutations of the ultimate rise of Artificial General Intelligence (AGI). An AGI system would be capable of operating to complete general tasks as opposed to the narrow task set that current AI are limited to. Many predictions describe various doom scenarios that could potentially arrive if AGI were to be developed.[189] Other writers are certain that AGI is impossible and will never be realized.[190] Ultimately, military application of AI does not rely on AGM ever becoming a reality nor is it concerned with the possible consequences of this occurring. As previously discussed in Chapter 3, development of narrow AI applications of AI is ongoing and many real world products already exist and are in service. If new breakthroughs did not occur, and instead further development was limited to current technology there would still be vast scope of applications to be implemented. Military applications of AI do not rely on a general AI algorithm to be incredibly useful and offer valuable improvements over non AI imbued technologies. Governments should ensure that policy is developed to deal with AGI long before it becomes a possibility. The argument of whether or not AI will change the way military's operate is over. AI, in its current state, has the capacity to improve all aspects of a military's functioning. The lag between technological breakthrough and implementation is the time required for design and testing of the new systems, which use

[189] Torres, "The Possibility and Risks of Artificial General Intelligence."

[190] Fjelland Ragnar, "Why General Artificial Intelligence Will Not Be Realized," *Humanities and Social Sciences Communications* 7, no. 1 (2020): 1–9, https://doi.org/10.1057/s41599-020-0494-4.

this technology. The F35 fighter for example took decades of development before it went into service.[191] It can be expected that the next decade will see an increasing rate of new AI capable military platforms brought into service.

The development of AI is an intensive task requiring time and resources to see progress. It is not a perfect technology, like any other military capability, it has its strengths and its weaknesses. There are significant hurdles that must be overcome before the world's militaries implement AI solutions across the breadth of their operations. The technology will continually evolve as vulnerabilities are discovered, exploited, and defended against. It is likely that the technology will evolve steadily at times, and jump ahead disruptively at other times. Debates about whether the field of research will ever reach AGI are valid, but from a military standpoint, irrelevant.

[191] Sebastien Robiln, "The Crazy Story of How the Stealth F-35 Fighter Was Born," *The National Interest* (blog), February 24, 2019, https://nationalinterest.org/blog/buzz/crazy-story-how-stealth-f-35-fighter-was-born-45387.

CHAPTER 6 – CONCLUSION

The story of AI from inception to present day has been a long flat trajectory ending in a steep upwards arc. Several technological trends all created the conditions to finally bring AI into its heyday. Computing power had roughly followed Moore's law for decades, huge datasets had been generated and made openly available to researchers, and researchers made algorithmic breakthroughs that used that data and computing power to make breakthroughs in AI computing. There are untold numbers of AI applications that are used in daily life, albeit invisible to the end-user. AI algorithms seek to keep social networking users engaged, video watchers entranced and cell phone microphones free from background noise. The algorithms are ready for widespread implementation into militaries in order to improve their overall effectiveness and efficiency. Massive swarms will now be possible, necessitating changing both offensive and defensive tactics. Smart weapons, will be capable of improved autonomy and precision, keeping soldiers safe from harms way while raising ethical concerns about the decision on which life to take. The field of logistics will see improvements in predictive capabilities, maintenance, transportation, supply, and manufacturing. Commanders will be enhanced by AI systems, which can collate and display overwhelming amounts of data in meaningful ways. When necessary, AI systems will be enabled to react with faster than human decision-making abilities in order to respond to critical threats. The field of cyber warfare will see improvements as AI programmers simultaneously seek out and fix gaps in cyber security infrastructure. The overwhelming applicability of AI to the military realm necessitates all militaries to adopt the technology in order to maintain their relative military power.

An examination of the US and its past and present adversaries, Russian and China, show that they have all invested in AI research and development and understand its importance. While Russia does not have the same level of resources to bring to bear, it has the potential to excel in specific areas of AI augmented warfare such as cyber war. China's combined population, economic might, and national strategy, have it on a path to compete with the US in terms of overall military power. Should the US not maintain its current level of investment in their Third Offset Strategy, they could see China use AI to improve its military power and become the most powerful military in the world.

The future of AI research is not guaranteed to continue to see results using the same fields of research that have currently seen results. The quest for a general AI system that can function at the same or superior cognitive capacity to humans may never be reached. Militaries will need to match pace with AI research or risk having their adversaries surpasses them. The near future of warfare will be marked by the widespread adoption of AI.

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