

ARTIFICIAL INTELLIGENCE: WHAT SHOULD THE CANADIAN ARMY FOCUS ON?

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General Studies

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

ARTIFICIAL INTELLIGENCE: WHAT SHOULD THE CANADIAN ARMY FOCUS ON?, by Major Jérôme J.N.G. Duval, 128 pages.

The Canadian Army acknowledges the importance of Artificial Intelligence in its modernization strategy. Still, it lacks focus on what functions of AI need to be pursued in the short, mid, and long-term. Focus is particularly critical to the Canadian Army as it has more limited human and financial resources to invest in research than its main ally and adversaries. Therefore, prioritization is needed for research and investments to ensure the Canadian Armed Forces and Canada's Army do not fall behind. This study examines various promising applications of artificial intelligence, reviews the Canadian Army modernization strategies, and investigates what Canada's main ally and adversaries are currently focusing on to make practical recommendations for decision-makers and staff working on modernization. Using a ranking system to predict the ability to impact the Canadian Army operations, the conclusions recommend pursuing nine specific AI-enabled applications for land warfare and offer recommendations for operationalizing artificial intelligence within the next 15 years. Ultimately, this study is relevant for any military professionals, Defence team members, and researchers interested in the potential applications of AI and ML in land warfare.

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TABLE OF CONTENTS

	Page
MASTER OF MILITARY ART AND SCIENCE THESIS APPROVAL PAGE	iii
ABSTRACT.....	iv
ACKNOWLEDGMENTS	v
TABLE OF CONTENTS.....	vi
ACRONYMS.....	ix
ILLUSTRATIONS	x
TABLES	xi
CHAPTER 1 INTRODUCTION	1
Background.....	1
Problem Statement.....	4
Purpose of the Study	5
Research Questions.....	5
Assumptions.....	6
Definition of Terms	7
Scope.....	11
Limitations and Delimitations	13
Significance of the Study	15
Summary	16
CHAPTER 2 LITERATURE REVIEW	17
Introduction.....	17
AI and Its Potential Army Application in Horizons 1 and 2	18
Canadian Army Doctrine, Policies, and Publications.....	26
Strong, Secure, Engaged: Canada's Defence Policy.....	27
Close Engagement	28
Leveraging Artificial Intelligence for Canada's Army	30
Advancing with Purpose	35
Main Ally (United States).....	39
Main Adversaries (China and Russia)	52
China	53
Russia.....	57
Summary	60

CHAPTER 3 RESEARCH METHODOLOGY	62
Introduction.....	62
Method	63
Data Collection	65
Data Analysis	66
Ethical Considerations	69
CHAPTER 4 ANALYSIS	71
AI-Enabled Applications Selection	72
Command.....	74
High-Frequency Wargame Simulator	74
Friendly and Enemy Course of Action (COA) Generator	74
Sense	75
Imagery Analysis Platform, Including Tools Focused on Identifying Visual Disinformation (Deepfake, etc.)	75
Cultural and Sentiment Understanding.....	76
Act.....	77
Electromagnetic Spectrum (EMS) AI-enabled Technology to Jam, Blind, and Deceive the Enemy	77
Shield	77
Protection of Networks (Cyber & EMS)	77
Semi-Autonomous Perimeter Air-Defense (GBAD).....	78
Sustain.....	79
Control of Overall Logistics Capability (Smart Defence Resource Management Information System (DRMIS)	79
Drones/Robots for Delivery and Return of Logistics	79
Training.....	80
DATE AI-enabled Enemies and Adversaries Part of an Immersive Digital Environment for Simulation Purposes	80
Comparison and Results Explanation	83
Digitization and Enhanced Networking.....	86
One Army.....	87
Interoperable	87
Simplicity	88
ADO Ready.....	90
Versatility.....	91
Build Trust	92
Results Analysis and Recommendations	94
CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS	101
Scope and Purpose	102
Summary Recommendations	103
Unexpected Recommendations.....	104

Recommendations for Subsequent Research	107
Closing Thought	108
APPENDIX A DEFINITION OF THE CANADIAN ARMY MODERNIZATION PRINCIPLES	110
APPENDIX B THE ARMY IN MULTI-DOMAIN OPERATIONS – LOGIC MAP	112
BIBLIOGRAPHY	113

ACRONYMS

AI	Artificial Intelligence
ARes	Canadian Army Reserve
CA	Canadian Army
CAF	Canadian Armed Forces
CALWC	Canadian Army Land Warfare Center
CCP	Chinese Communist Party
CE	Close Engagement, Land Power in an Age of Uncertainty
COA	Course of Action
EW	Electronic Warfare
LAWS	Lethal Autonomous Weapons Systems
LSCO	Large Scale Combat Operations
ML	Machine Learning
MDO	Multi-Domain Operations
MDMP	Military Decision Making Process
OPP	Operational Planning Process
PLA	People's Liberation Army
RMA	Revolution in Military Affairs
SSE	Strong, Secure, Engaged: Canada's Defence Policy
US Army	United States Army
VPA	Virtual Personal Assistant

ILLUSTRATIONS

	Page
Figure 1. Publication of National AI Strategies	3
Figure 2. Simplified Diagrams of Handcrafted Knowledge and Machine Learning AI	8
Figure 3. DARPA “AI Waves” Framework with a Simplified Depiction of Types of AI	9
Figure 4. Literature Review’s Framework – Military Applications of AI (Army)	18
Figure 5. Literature Review’s Framework – Canadian Army	26
Figure 6. Literature Review’s Framework – Allies	39
Figure 7. US Army AI Lines of Effort and Implementation Timeline	45
Figure 8. Literature Review’s Framework – Adversaries	52
Figure 9. Methodology Flow Chart	64
Figure 10. Findings	71
Figure 11. Methodology Flow Chart	85
Figure 12. Thesis’ Summary	102

TABLES

	Page
Table 1. CA Operational Functions and Equivalent US Army Warfighting Functions ...	13
Table 2. List of AI Land Warfare Applications by Operational Function.....	22
Table 3. Measuring Scale Used for Comparing AI-Enabled Applications.....	67
Table 4. Table Used for Comparing AI-Enabled Applications	69
Table 5. Table Used for Ranking of AI-Enabled Applications to Pursue in Horizons 1 & 2	69
Table 6. Considered Applications Not Used in Final Comparison.....	82
Table 7. AI-Enabled Applications Comparison.....	84
Table 8. Ranking of AI-Enabled Applications to Pursue for Horizons 1 & 2	95
Table 9. Rankings of AI-Enabled Applications Separated by Horizon	95
Table 10. Ranking of AI-Enabled Applications to Pursue in Horizons 1 & 2 - without “Build Trust”	97
Table 11. Rankings of AI-Enabled Applications Separated by Horizon – without “Build Trust”	97
Table 12. Final Ranking of AI-Enabled Applications to Pursue for Horizons 1 & 2.....	98
Table 13. Final Ranking - AI Applications the CA Should Pursue in Order of Priorities	99
Table 14. Final Ranking - AI Applications the CA Should Pursue in Order of Priority	104

CHAPTER 1

INTRODUCTION

Background

Since the beginning of warfare, groups, tribes, and nations have tried to get an asymmetrical advantage over their adversaries or enemies. As explained by Knox and Murray in *The Dynamics of Military Revolution, 1300-2050*, Revolutions in Military Affairs (RMA) have often given tactical, operational, and/or strategic victories to the nation that developed these revolutions first. These RMAs are sometimes based on technology, but more often than not, they are in conjunction with important changes in technology, doctrine, strategies, or tactics. Technology alone normally does not provide asymmetrical advantages, but technology combined with new doctrine and tactics can make the difference with winning or losing a battle, an operation, or even a war.¹ A few examples of technology coupled with doctrine have proven the effect of asymmetrical advantages in warfare: the invention of the crossbow; nuclear bombs that precipitated the

¹ Macgregor Knox and Williamson Murray, "Thinking about Revolutions in Warfare," in *The Dynamics of Military Revolution, 1300-2050*, ed. Macgregor Knox and Williamson Murray (New York: Cambridge University Press, 2001), 1-14. In this book, Knox and Murray seek to understand RMAs and military revolutions. They do not provide clear definitions, but still describe these phenomena in detail:

(1) Military revolutions: They "fundamentally change the framework of war" and "brought systemic changes in politics and society. They were uncontrollable, unpredictable, and unforeseeable." Knox and Murray, "Thinking about Revolutions in Warfare," 6-7.

(2) Revolution in military affairs (RMAs): "The record of the past nevertheless suggests the existence ... of clusters of less all-embracing changes [than military revolutions]. ... They do appear susceptible to human direction, and in fostering them, military institutions that are intellectually alert can gain significant advantage." Knox and Murray, "Thinking about Revolutions in Warfare, 12.

end of the Second World War; or computer and command and control (C2) systems that enabled the coalition victory during Operation Desert Storm.

In a large part due to this eternal quest to find the next RMA, military forces around the world are continuously on the hunt for the next technology that will give them an asymmetrical advantage in the next war. Even if we could argue against the actual relevance of RMAs in the outcome of wars, the fact that nations around the world have been forever looking for technological advantages against their adversaries is undisputable. Today is not an exception to this rule, therefore the question to ask is what technology, coupled with new tactics and doctrine, has the potential to give an asymmetrical advantage in future wars? Some argue that Artificial intelligence (AI) could be one of three things: the next RMA, an extension of recent Information Technology enabled RMA, or even a military revolution.² For this reason, AI is one of the most, if not the most, discussed “future capability” topics in public, academic, or military institutions at the moment.

Canada is not an exception to this tendency and is, surprisingly for some, one of the most important countries in AI development around the globe. In 2017, it was even the first country to publish a general strategy on AI with its *Pan-Canadian AI Strategy* (see figure 1) and in doing so became the first nation “to articulate an approach to AI and

² Jean-Cristophe Noël, “Intelligence artificielle : vers une nouvelle révolution militaire?” *Focus stratégique*, no. 84 (Ifri, 2018), 32-35.

more importantly, commit to spend money towards it,”³ according to Christian H. Breede who has studied and compared the AI policy of ten countries.

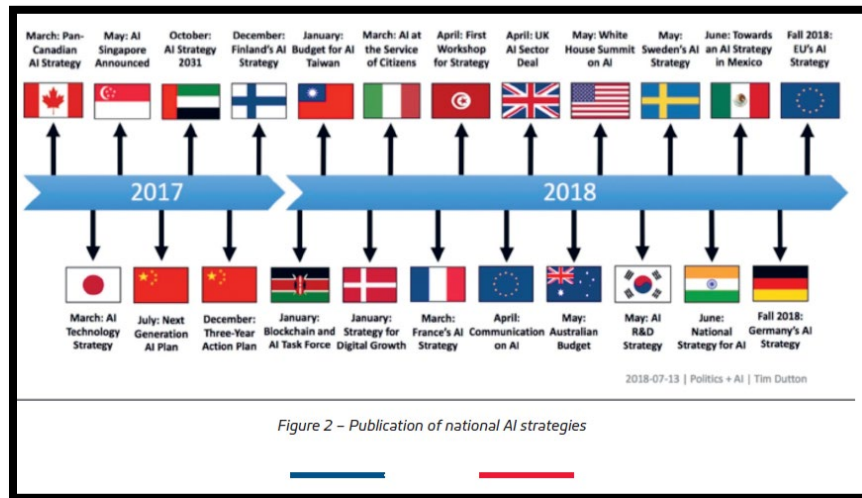


Figure 1. Publication of National AI Strategies

Source: Government of France, *Artificial Intelligence in Support of Defence*, Report of the AI Task Force (Paris, France: Ministère des Armées, September 2019), 8.

Furthermore, Tortoise Media has recently placed Canada fourth, right after the United States (US), the United Kingdom (UK), and China, in an “index to benchmark nations on their level of investment, innovation, and implementation of artificial intelligence.”⁴ If Canada has been and is still potentially a leader in this technology, what about the Department of National Defence (DND) and the Canadian Armed Forces (CAF)? Is DND ranked fourth on the global stage in AI military investment, innovation,

³ H. Christian Breede, “The Bleeding Edge of War: A Comparative Study of Artificial Intelligence Defence Readiness,” (unpublished paper, n.d.), 1.

⁴ Tortoise Media, “The Global AI Index,” Tortoise, 2021, <https://www.tortoisemedia.com/intelligence/global-ai/>.

and implementation? With a small budget compared to its GDP and a relatively small number of troops and human resources, it would most likely rank lower if such a ranking existed.⁵ The Canadian Army (CA), being the biggest and the most visible service in the CAF, has no choice other than participating in this AI “arms race” aimed at getting the next asymmetrical advantage before our adversaries. This is even more relevant as Kissinger, Schmidt, and Huttenlocher predict in their latest book on artificial intelligence and machine learning that a potential political, societal, and national security divide may occur between nations that espouse AI development and the ones that do not.⁶

Problem Statement

The Canadian Army acknowledges the importance of Artificial Intelligence (AI) in the future Operational Environment as described in A-PP-106, *Advancing with Purpose*,⁷ and B-GL-310-001, *Close Engagement, Land Power in an Age of Uncertainty* (CE),⁸ but lacks focus in what forms of AI need to be pursued in the short, mid, and long-

⁵ The Center for International and Defence Policy, Queen’s University, “Dr. H. Christian Breede: The Bleeding Edge of War: Assessing the Gap in AI and Defence Policy,” January 22, 2020, Video of lecture, 42:30, <https://www.youtube.com/watch?v=BdJPWIuhdow>.

⁶ Henry A. Kissinger, Eric Schmidt, and Daniel Huttenlocher, *The Age of AI: And Our Human Future* (New York: Little, Brown and Company, 2021), 166-176.

⁷ Canada, Department of National Defence, *Advancing with Purpose: The Canadian Army Modernization Strategy*, 4th ed. (Ottawa, ON: Headquarters, Canadian Army, December 2020), 52. http://www.army-armee.forces.gc.ca/assets/ARMY_Internet/docs/en/national/2021-01-canadian-army-modernization-en.pdf.

⁸ Canada, Department of National Defence, B-GL-310-001/AG-001, *Close Engagement, Land Power in an Age of Uncertainty* (Kingston, ON: Canadian Army, 2019), 26, http://www.army-armee.forces.gc.ca/assets/ARMY_Internet/docs/en/close-engagement.pdf.

term. Focus is particularly critical to the Canadian Army as it has more limited human and financial resources to invest in research than its main allies and adversaries.

Therefore, thorough analysis and prioritization are needed in research and investments to ensure the Canadian Armed Forces and the Canadian Army do not fall behind their main allies and, more importantly, their main adversaries.

Purpose of the Study

The purpose of this study is to make recommendations to the Canadian Army in general and to the Canadian Army Land Warfare Center (CALWC) more specifically on what form and function of AI should the Canadian Army focus on for research and investment in the short, and mid-term. In other words, the intent is to develop well-informed practical recommendations for decision-makers and inform military professionals interested in the potential applications of AI and ML. Furthermore, this study aims to humbly contribute to current discussions on this topic from a combat arms perspective at the tactical and operational levels.

Research Questions

The primary research question of this thesis is the following: using a ranking system to predict the ability to impact the Canadian Army operations, what functions of Artificial Intelligence should the Canadian Army pursue with 5- and 15-year timeframes (horizons 1 and 2)? To answer this overarching question, three secondary research questions will be looked upon:

1. What forms and functions of AI have the most potential military application within horizons 1 and 2?

2. What is Canada's strategic military framework on AI and are there any considerations, constraints, and/or limitations specific to the Canadian Army that could influence the adoption or development of a specific function or type of AI?
3. What are our main allies and adversaries currently predicting and focusing on?

Assumptions

A few assumptions will be used in conducting this study. First, it is assumed that the Canadian Army will prioritize capabilities that counter perceived threat advantages over Canadian capabilities that align well with threat vulnerabilities.⁹ A second assumption is that some relationship between Canadian priorities and those under development by close allies might warrant a lower priority in Canadian development if the capability could be shared (an American technology that would be implemented at NORAD for example) or would indicate a good idea for Canadian development if the capability will not be shared and is valued by an ally.¹⁰ A third assumption is that AI technology will develop as per the horizon's timelines described in the Department of National Defence key publications. As in any military plan, it will not happen as envisioned, but making this assumption is essential to project the Canadian Army in the future and facilitate the formulation of relevant recommendations. A fourth and final

⁹ Dale Spurlin, reply to "Artificial Intelligence: What should the Canadian Army focus on?," (A211 Discussion Area, Blackboard Collaborate, October 12, 2021), https://cgsc.blackboard.com/webapps/discussionboard/do/message?action=list_messages&course_id=_11575_1&nav=discussion_board_entry&conf_id=_200557_1&forum_id=_229265_1&message_id=_572472_1.

¹⁰ Ibid.

assumption is that General and Super AI will not break through in horizons 1 and 2. Yes, general AI could start being a thing at the end of horizon 2 (15 years from now) but will not be mature enough to be implemented in mass in any Army of the world. Obviously, if this happens, the conclusions of this study would need to be reviewed and reanalyzed.

Definition of Terms

The definition of AI is still debated in academic and practitioner circles.¹¹ The aim of this research is not to enter this specific debate. Because the purpose of this study is to make recommendations to the Canadian Army and because the Department of National Defence's (DND) definition is broad enough, this definition will be used throughout this research: "Artificial intelligence is the capability of a computer to perform such functions that are associated with human logic such as reasoning, learning and self-improvement."¹²

Another important concept that needs to be defined is Machine Learning (ML). Machine Learning is a subcategory of AI and needs to be contrasted with the first broad category of AI that was invented and theorized in the middle of the 19th century: Handcrafted Knowledge AI. In *Understanding AI Technology*, Greg Allen explains that:

¹¹ *The Age of AI* by Kissinger, Schmidt, and Huttenlocher, offers a good overview of the evolution of the definition of AI in chapter 3 of their book. Kissinger, Schmidt, and Huttenlocher, *The Age of AI*, 55-59. For the US Department of Defense (DoD) definition, see: Greg Allen, *Understanding AI Technology*, Technical Report (Washington, DC: Joint Artificial Intelligence Center, Department of Defense, April 2020), 5.

¹² Government of Canada, "Artificial Intelligence," Termium Plus, last modified December 8, 2021, https://www.btb.termiumplus.gc.ca/tpv2alpha/alpha-eng.html?lang=eng&srchtxt=ARTIFICIAL%20INTELLIGENCE&i=&index=enb&sg_kp_wet=421453&fchrcrdnm=3#fichsauve-saverecord3.

The key difference between a Handcrafted Knowledge System and a Machine Learning system is in where it receives its knowledge. Rather than having their knowledge be provided by humans in the form of hand-programmed rules, Machine Learning systems generate their own rules. For Machine Learning systems, humans provide the system training data. By running a human-generated algorithm on the training dataset, the Machine Learning system generates the rules such that it can receive input x and provide correct output y .¹³

In other words, ML systems learn from examples provided by data and not by being directly programmed like Handcrafted Knowledge AI. Figure 2 below depicts the differences between the two categories:

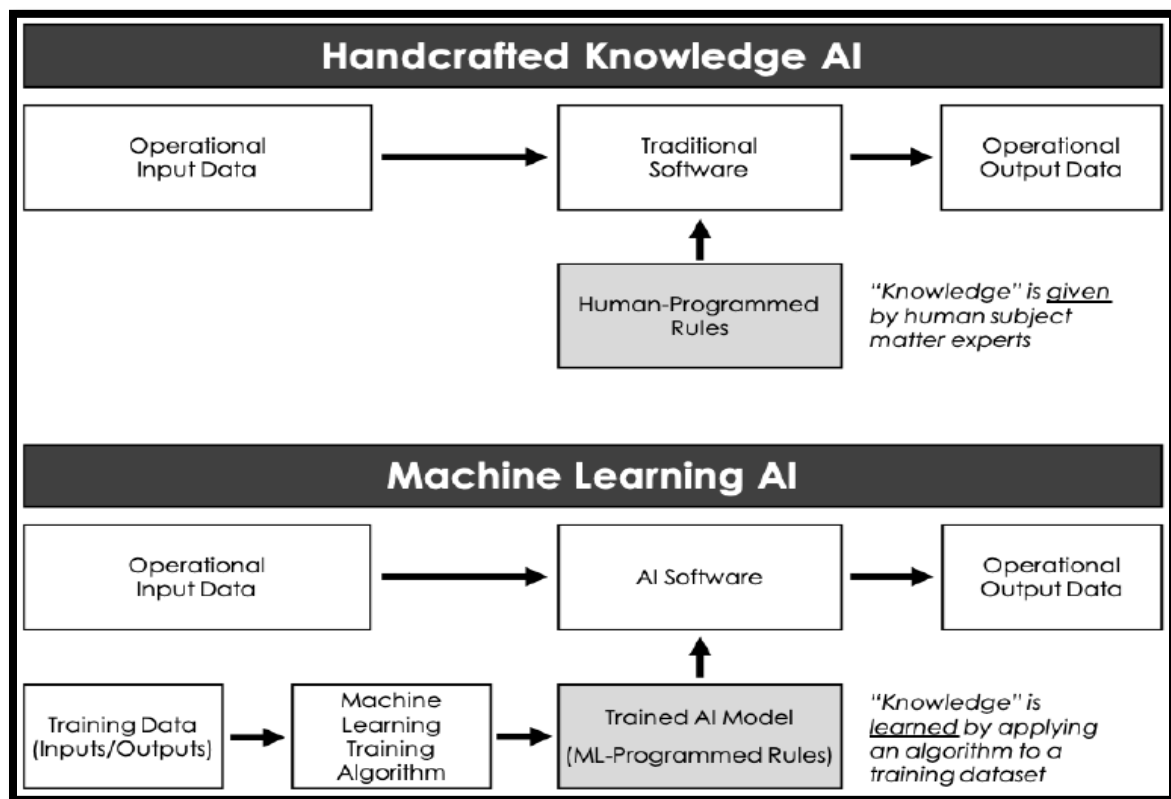


Figure 2. Simplified Diagrams of Handcrafted Knowledge and Machine Learning AI

Source: Greg Allen, *Understanding AI Technology*, Technical Report (Washington, DC: Joint Artificial Intelligence Center, Department of Defense, April 2020), 8.

¹³ Allen, *Understanding AI Technology*, 7.

Furthermore, there are different types of Machine Learning algorithms. Four broad families of ML are systematically mentioned in the literature: supervised, unsupervised, semi-supervised, and reinforcement (illustrated in figure 3).¹⁴ Several other types of ML algorithms exist, the more known being Deep Neural Networks (a.k.a. Deep Learning), transformers, and generative adversarial networks (GANs).¹⁵ These sub-categories of ML will not be described and defined in detail in this research as it is not the technology itself that is being studied, but the application of AI for the Canadian Army.

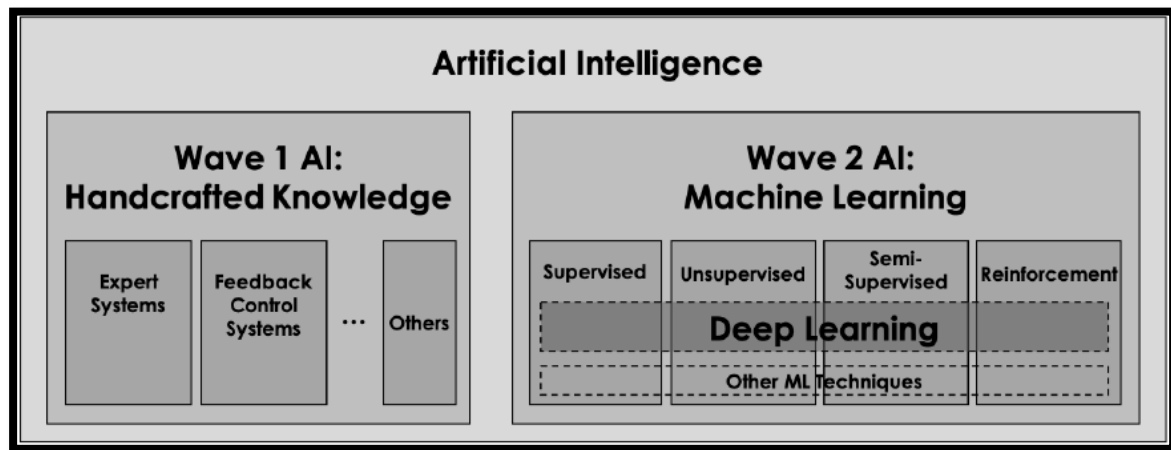


Figure 3. DARPA "AI Waves" Framework with a Simplified Depiction of Types of AI

Source: Greg Allen, *Understanding AI Technology*, Technical Report (Washington, DC: Joint Artificial Intelligence Center, Department of Defense, April 2020), 17.

¹⁴ Allen, *Understanding AI Technology*, 11-16.

¹⁵ Kissinger, Schmidt, and Huttenlocher, *The Age of AI*, 14, 73-74.

Horizons 1 and 2 are also important to define in this research. These concepts are defined in *Canada's Future Army*, Vol. 1, *Methodology, Perspectives, and Approaches*, which is the CA publication that provides “the methodological guidance and initial estimate of the future security environment (FSE) for the 2040 timeframe.”¹⁶ As this study aims to be useful for Canadian Army decision-makers, the doctrinal definitions of these concepts will be used throughout.

1. Horizon 1, also known as the Army of Today, “has a 0–5-year outlook and is roughly correlated with the Build stage of the continuum,”¹⁷ the Build phase being the step where “validated designs for force capabilities are refined and realized for use in the field.”¹⁸

2. Horizon 2, also known as the Army of Tomorrow, “has a 5–15-year outlook and is roughly correlated with the Design stage of the continuum,”¹⁹ the Design stage being the step where “selected capability requirements are translated into validated designs for future use.”²⁰

With these definitions in mind, horizon 1 in this study is from 2022 to 2027, and horizon 2 is from 2027 to 2037.

¹⁶ Canada, Department of National Defence, *Canada's Future Army*, vol. 1, *Methodology, Perspectives and Approaches* (Kingston, ON: Canadian Army Land Warfare Center, 2015), 7, https://publications.gc.ca/collections/collection_2017/mdn-dnd/D2-354-1-2015-eng.pdf.

¹⁷ Ibid., 18.

¹⁸ Ibid., 7.

¹⁹ Ibid.

²⁰ Ibid.

Scope

The scope of this study will first be limited to the Canadian Army. A few mentions will be made of the other services, but will keep the Army at the center of the study. However, it is crucial to note that even if land operations are the clear focus of this research, other domains intersect and enable land warfare. Hence, this study will traverse directly and indirectly other domains, the cyber and cognitive domains being the most prominent ones. Second, the focus will be on the functional aspects of AI at the operational and tactical levels. It means this research will not discuss AI at the strategic level, nor down below at the technical or engineering level. In a similar fashion as Guderian, Liddell Hart, Fuller, and De Gaulle did during the inter-war period,²¹ the intent is to identify how AI can be employed practically and doctrinally, but not how AI needs to be engineered and implemented in military technologies. For example, J.F.C. Fuller and Guderian's writings were not focused on the mechanical technicalities of tanks, but on how to implement armoured warfare successfully to win battles, operations, and war. Third, the scope of this study will be practical in nature but will keep a wide perspective on how ML could be used in each of the warfighting functions.

On purpose, the scope of this research will not include ethical considerations of artificial intelligence. It does not mean that it is not an important aspect of AI. It is quite the opposite. Ethics of emergent technologies necessitate detailed and thorough research and analysis that cannot be covered in enough detail here. Furthermore, there is already a

²¹ Williamson A. Murray, "Armored Warfare: The British, French, and German experiences", in *Military Innovation in the Interwar Period*, ed. Williamson A. Murray and Allan R. Millett (Cambridge, UK: Cambridge University Press, 1996), 6-49.

vast literature on the subject. In fact, multiple articles and papers are written every year on this specific subject in military and civilian academia. However, from a consequentialist or utilitarian perspective, artificial intelligence is and will be used by our allies and adversaries. For this reason, artificial intelligence also needs to be studied from a functional perspective without putting ethical considerations at the forefront. It is what this specific research aims to accomplish.

To note, because the author of this research is a Canadian Army officer studying in the US Army Command and General Staff College (CGSC), both Canadian Army and US Army doctrinal concepts will be used in this research, sometimes interchangeably. For example, the Canadian Army operational functions of command, sense, act, shield, and sustain²² will be used interchangeably with the US Army warfighting functions of command and control, intelligence, movement and maneuver, fires, protection, and sustainment.²³ To note, the warfighting function of “Fires” is part of the operational function of “Act” in the Canadian Army. There are minor differences between the US and Canadian warfighting and operational functions, but they are not important enough to impede the comprehension of the concepts and analysis provided in this research. Table 1 below shows how Canadian Army operational functions synchronize with the U.S. Army warfighting functions.

²² Department of National Defence, *Close Engagement*, 42.

²³ Headquarters, Department of the Army, Army Doctrine Publication 3-0, *Operations* (Washington, DC: Army Publishing Directorate, 31 July 2019), 58-62.

Table 1. CA Operational Functions and Equivalent US Army Warfighting Functions

Operational Functions	Warfighting Functions
Command	Command and Control
Act	Movement and Maneuver
	Fires
Sense	Intelligence
Sustain	Sustainment
Shield	Protection

Source: Created by author.

Limitations and Delimitations

Limitations need to be imposed on this study as in any research. The first limitation is the time available. Only nine months have been used to complete all requirements of this thesis as part of the Master of military art and science program (MMAS), and it was done in parallel of completing the Command General Staff Officer Course. Consequently, limited time was allotted to complete this study. A second limitation is the limited generalization offered by this study. As a qualitative methodology was used throughout, the results cannot be generalized to the population because they lack statistical strength. As well, it may be difficult to generalize the conclusions of this research to all other nations, as Canada and the Canadian Army have specific characteristics like culture, values, budget, capabilities, strengths, and weaknesses. However, one could argue that this research could be used by other “medium power” nations or by anyone interested in the operationalization of AI in the next 15 years.

For delimitations, the most prominent is that only horizons 1 and 2 will be studied and analyzed. It means that from a “future operation” perspective, only the short and midterm will be discussed. In more practical terms, it signifies that no artificial general intelligence (AGI) or “super-AI” (ASI) potential uses will be discussed.²⁴ Another important delimitation is that this study will only focus on a few allies and adversaries due to a lack of time and resources. More specifically, this thesis will only focus on Canada, and the US for the allies, then China, and Russia for the adversaries. A more comprehensive study of other allies and adversaries like the United Kingdom, Australia, New Zealand, France, Israel, Iran, or North Korea, to name a few, would have added to the preciseness and relevance of the analysis. However, too broad a research would be as detrimental as an over-narrow one. Still, this thesis is a good starting point to expand research in studying and analyzing other allies and partners in subsequent research, specifically the other “five eyes” nations and other comparable medium-power nations, more similar in size and resources than the United States of America. More will be discussed on the selection of states in the literature review, specifically in the section titled “Main Ally (United States)” in chapter 2.

Another delimitation is that only open-source and unclassified documents have been used. The fact that the author is a Canadian officer working in the United States is an important reason for this, but certainly not the only one. This thesis aims at being practical and accessible to Canadian Army decision-makers and to any members of the

²⁴ The levels of artificial intelligence, including AGI and ASI, will be defined and further discussed at the beginning of the literature review.

profession of arms who is interested in the capabilities of AI and ML on the battlefield, hence the choice to keep this study at the unclassified level.

The last delimitation is that no AI and ML subject matter experts were interviewed or formally approached before or after data analysis to verify the findings further. Therefore, this study's descriptive analysis and recommendations are subjective as they are the result of the research of one individual: the author of this thesis. His formal and informal education, military training and experiences as an Infantry Officer, and most recent education at the US Army Command and General Staff College consequently taint this study. The methodology used for data collection and analysis was selected to compensate for these biases. More details on methodology will follow in chapter 3.

Significance of the Study

This study aims to be relevant to the Canadian Army and CALWC by focusing on the most promising technologies and functions of AI and ML. As suggestions by CALWC members directly inspired the primary question, the potential for relevance and significance for the Canadian Army is high. As well, it could be significant for senior military decision-makers as it will give them the tools to make decisions on the development of this promising technology. Finally, by being practical and simple in its form, it will surely contribute to educating officers, non-commissioned officers (NCOs), and soldiers on this technology that is often non-realistically portrayed by science-fiction, pop culture, and mass media.

Summary

In summary, the Canadian Army needs to focus its limited resources and efforts to compete against allies and adversaries in the new arms race of artificial intelligence.

Therefore, this study aims to provide recommendations to the Canadian Army on what forms and functions of AI it should focus on for research and investment in the short, mid, and long-term. To accomplish this purpose, the principal research question that will be used will be as follows: using a ranking system to predict the ability to impact the Canadian Army operations, what forms of Artificial Intelligence should the Canadian Army pursue with 5 and 15-year timeframes (horizons 1 and 2)?

Before explaining the methodology in chapter 3, then collecting data and providing analysis in chapter 4, one must review and synthesize the literature. Therefore, the next chapter, chapter 2, will explain the results of the literature review conducted as part of this research using four themes inspired by the primary and secondary research questions.

CHAPTER 2

LITERATURE REVIEW

Introduction

This chapter aims at summarizing and synthesizing the reviewed literature and scholarship to discuss those sources in conversation with each other. For recall, here are the primary and secondary research questions. The primary research question is: using a ranking system to predict the ability to impact the Canadian Army operations, what functions of Artificial Intelligence should the Canadian Army pursue with 5 and 15-year timeframes (horizons 1 and 2)? Secondary research questions are: (1) what forms and functions of AI have the most potential military application within horizons 1 and 2; (2) what is Canada's strategic military framework on AI and are there any considerations, constraints, and/or limitations specific to the Canadian Army that could influence the adoption or development of a specific function or type of AI; (3) what are our main allies and adversaries currently predicting and focusing on?

AI and Its Potential Army Application in Horizons 1 and 2

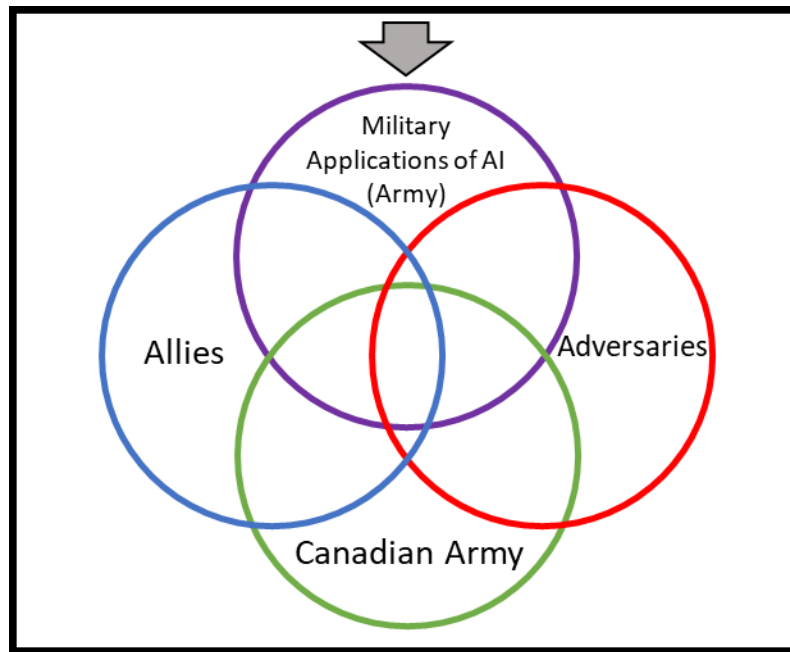


Figure 4. Literature Review's Framework – Military Applications of AI (Army)

Source: Created by author.

In reviewing the literature on the application of AI in land warfare for the next 15 years, three findings are recurrent: (1) AI will most likely have a steady development in the foreseeable future, but it is unlikely that artificial general intelligence (AGI) will make a significant breakthrough in this timeframe; (2) AI and ML have the potential of having a significant impact on all aspects of warfare, so all warfighting functions can be enabled by this technology; (3) AI-enabled systems and technologies are still brittle and inconsistent, therefore will require human operators “in-the-loop” or “on-the-loop” to control and optimally make final decisions. The following few paragraphs will be

devoted to explaining these central themes and how authors and academics are debating these questions.

The book *The Age of AI: And Our Human Future*, by the well-known authors Henry A. Kissinger, Eric Schmidt, and Daniel Huttenlocher, discuss at length the three levels of AI, which are Artificial Narrow Intelligence (ANI), Artificial general intelligence (AGI), and artificial superintelligence (ASI). Here is how the authors define ANI and AGI:

Some developers are pushing the frontiers of machine-learning techniques to create what has been dubbed artificial general intelligence (AGI). Like AI, AGI has no precise definition. However, it is generally understood to mean AI capable of completing any intellectual task humans are capable of – in contrast to today’s “narrow” AI, which is developed to complete a specific task.²⁵

And now, here is how Army Futures Command defines the same concepts:

Researchers divide AI into two distinct categories – general and narrow. General AI (also known as Artificial General Intelligence) is a “system that exhibits intelligence comparable to that of a human or beyond, across the range of contexts in which a human might interact.” ... Narrow AI, the only type that exists today, are “applications that provide domain-specific expertise or task completion.”²⁶

Beyond these definitions, what is essential for this study is that narrow intelligence will dominate horizons 1 and 2. One could argue that if the steady pace of AI and ML development continues at the same rate as in the last decade,²⁷ AGI could emerge quicker

²⁵ Kissinger, Schmidt, and Huttenlocher, *The Age of AI*, 88.

²⁶ Future Warfare Division, Directorate of Concepts, *Future Study Plan 2019: Operationalizing Artificial Intelligence for Multi-Domain Operations* (Fort Eustis, VA: Futures and Concepts Center, Army Futures Command, August 2019), 2-3.

²⁷ Forrest E. Morgan, Benjamin Boudreaux, Andrew J. Lohn, Mark Ashby, Christian Curriden, Kelly Klima, and Derek Grossman, *Military Applications of Artificial Intelligence: Ethical Concerns in an Uncertain World* (Santa Monica, CA: Rand

than expected. It is potentially true, but at the slow pace of military procurement in Canada and NATO countries, it is nearly impossible that AGI could be truly implemented at the operational or tactical level within a 15-year timeframe. As mentioned by the Futures and Concepts Center from the Army Futures Command, “General AI does not exist today and the timeframe (ranging from several years to never) of its emergence and operational application is an unsettled controversy among leading researchers and scientists.”²⁸ Moreover, narrow AI is still at its beginning and has a lot to offer. It is revolutionary in its own right and is the only type of AI available in the foreseeable future.

It means for this specific study that all applications that will be considered are narrow in focus and in line with what ANI can offer. Therefore, all potential AGI and ASI-enabled systems and technologies will be dismissed from this study as they are still more science-fiction than reality.

The second common conclusion found in the studied literature is that, unsurprisingly, AI and ML can have a significant impact on all aspects of warfare,²⁹ land warfare included, which means that this technology can enable all operational or warfighting functions. Each Canadian and US publication analyzed was dividing the

Corporation, 2020), 118-119, https://www.rand.org/content/dam/rand/pubs/research_reports/RR3100/RR3139-1/RAND_RR3139-1.pdf

²⁸ Future Warfare Division, Directorate of Concepts, *Future Study Plan 2019*, 3.

²⁹ Recommendation from the Rand Corporation to the US Air Force in 2020: “Organize, train, and equip forces to prevail in a world in which military systems empowered by AI are prominent in all domains.” Morgan et al., *Military Applications of Artificial Intelligence*, 125.

current and potential uses of AI and ML within these functions. However, some articles and government sources included training or simulation in categorizing the possible use of AI. For example, Priems and Gizewski describe how “development of immersive digital environments to help train soldiers”³⁰ could be used to train Army personnel better at a potentially lower cost. However, where does “training” fit in the operational functions? In fact, it can fit in any of them and in no one at all. Each function requires training and a simulated environment, digital or analog, but does not encompass training as a concept to enable simulation technology. For this reason, training will be added as a function analyzed in this research to make sure it is not forgotten as it is one of the earliest concrete applications envisioned by the US Army in their *2020 Army Artificial Intelligence Strategy*.³¹

Many current and potential AI land warfare applications are mentioned in all kinds of sources. A list of them has been gradually built to summarize the most salient in frequency and potential in reviewing the literature. Table 2 summarizes the most relevant for this research:

³⁰ Major Geoffrey Priems and Peter Gizewski, “Leveraging Artificial Intelligence for Canada’s Army: Current Possibilities and Future Challenges.” *Canadian Army Journal*, 19, no. 2 (2021): 45, http://www.army-armee.forces.gc.ca/assets/ARMY_Internet/docs/en/canadian-army-journal/caj-19-2-en.pdf.

³¹ “Starting in 2022, the Army will develop AI-enabled modules for insertion into the synthetic training environment to include agent-based adversaries at the small unit level, tutors, and patterns of behavior and life for more realistic scenarios. Expand this capability through 2028 to include dynamic mission rehearsal and integrated war gaming,” in Headquarters, Department of The Army (HQDA), *2020 Army Artificial Intelligence Strategy* (Washington, DC: Government Publishing Office, January 2021), 8.

Table 2. List of AI Land Warfare Applications by Operational Function	
Command	
Command and Planning	AI-enabled COA generator
	Risks and mitigation analysis
	High-frequency wargaming to identify risks, flaws, key considerations, and for comparing COAs.
	Commander's decision-making assistant
	AI-enabled advisory support to legal advisors (LEGADs) and policy advisors (POLADs)
	Smart Virtual Personal Assistants (VPAs) to support navigation, communication, targeting, logistics, and health systems.
	AI-enabled language applications for real-time translation and the transcription of meetings.
Signals	Prioritize messages based on content (i.e. Routine, Priority, Immediate, Flash and Flash Override)
	Alliance communication and information sharing
Sense	
Intelligence Analysis	Imagery analysis (satellite imagery, videos, maps, etc.)
	SIGINT analysis
	Data mining of social networks and open sources to determine relationships, plans, patterns of life, and to confirm events, as well as the use of sentiment analysis to determine the specific or general feelings of a population upon explicitly stated feelings, or through non-verbal behaviors.
Sensors	Sensors enhancing to assist in determining targets (including targets of opportunity) and in notifying/cueing decision-makers.
	Conduct information collection and analysis to increase situational understanding (MDCOP)
	High-volume surveillance and reconnaissance
Act	
Movement & Manoeuver (including offensive Cyber and EMS)	Autonomous unmanned ground vehicles with direct fire capabilities
	AI-enhanced cyber offensive capabilities
	Smart Virtual Personal Assistants (VPAs) to support navigation, communication, and targeting
	Adaptive radar systems to jam and blind sensors and information networks
	Detect, identify, and penetrate high-risk areas with unmanned systems.
	Generate Information Operations tools like DeepFake, and other disinformation products
Fires	EMS deception-enabled targeting
	AI-enabled Information operations
	EMS deception-enabled targeting
	VPAs used to improve weapon accuracy and assess weapon impact on targets.

Shield	
Air Defence	Anti-missile or anti-projectile weapon systems
	Autonomous perimeter defense/ground-based air defence (GBAD) and similar anti-access / area denial (A2/AD)
Network Protection	Analysis of the electromagnetic (EM) environment (wired, optical, laser, wireless), security, and optimization of means and methods of communication.
	AI-enabled red teaming to test the system and act upon any intrusions by detected authorized and unauthorized users
	Guard against network failure, electronic warfare, and cyberattack
	Identify digital network anomalies and conduct autonomous cyber defensive measures to protect the network at a scale beyond human capacity
Others	Autonomous route clearance or demining systems
	Direct Fire Autonomous weapon system for perimeter defence
	Standoff detection of CBRN
	Smart adaptive clothing technology
Sustain	
Smart supply chain management	Historical and current data analysis employing predictive analytics to anticipate future sustainment requirements
	AI-enabled sensors installed to gather information such as vehicle diagnostic data, fuel consumption, mileage, tire wear, and track all work performed on a vehicle
Transport	Use of drone and other technology for autonomous delivery and return of logistics
Health Services	Expertise can be shared (virtually) closer to patients for local treatment by non-experts
	Provide personalized medical treatment plans, and robotic surgery
	Smart Virtual Personal Assistants (VPAs) to support logistics and health systems.

Source: Created by author using multiple sources.³²

Not all of these AI applications will be analyzed in this research to provide recommendations. Following the literature review and after answering the secondary

³² Priems and Gizewski, “Leveraging Artificial Intelligence for Canada’s Army”; Future Warfare Division, Directorate of Concepts, *Future Study Plan 2019*; Margarita Konaev and Samuel Bendett, “Russian AI-Enabled Combat Coming to a City Near You?” *War On The Rocks*, July 31, 2019, <https://warontherocks.com/2019/07/russian-ai-enabled-combat-coming-to-a-city-near-you/#:~:text=As%20announced%20by%20Russian%20military,vehicles%2C%20for%20better%20situational%20awareness;> Ryan Fedasiuk, Jennifer Melot, and Ben Murphy, *Harnessed Lightning: How the Chinese Military is Adopting Artificial Intelligence* (Washington, DC: Center for Security and Emerging Technology, Georgetown University, October 2021); Jeffrey Edmonds, Jeffrey, Samuel Bendett, Anya Fink, Mary Chesnut, Dmitry Gorenburg, Michael Kofman, Kasey Stricklin, and Julian Waller, *Artificial Intelligence and Autonomy in Russia* (Arlington, VA: Center for Naval Analyses, May 2021).

research questions, ten of them will be selected for further analysis in chapter 4, as explained in more detail in chapter 3, Methodology.

The third common theme found in the literature for potential AI Army applications is that AI-enabled systems and technologies are still brittle and inconsistent; therefore, it will require humans “in the loop” in horizons 1 and 2, at least until humans are used to working with machines in a human-machine teaming relationship. Here is how Priems and Gizewski describe the brittleness of AI and its implications:

Current capability is confined to the performance of discrete functions and the learning of specific tasks (e.g. narrow AI). The brittleness of AI technology is concerning. Brittleness is reflected by any algorithm that cannot generalize or adapt to conditions outside a narrow set of assumptions. For instance, with the addition of a few bits of graffiti, a stop sign can be read as a 45-mph speed limit sign. Application to circumstances involving excessive uncertainty can in fact be especially dangerous. Take, for example, the erroneous selection and prosecution of a friendly target such as a friendly fighter or civilian vehicle.³³

Similar finding was observed in the literature focused on the US, China and Russia, including translated sources, making this concern generalizable to all nations studied in this research. Obviously, human involvement can take different forms. Most sources describe two types of human involvement: “in-the-loop” and “on-the-loop.” In-the-loop means that a human takes action and “pulls the trigger” on a lethal or non-lethal AI-enabled system to use a common military analogy. Without him making a decision and taking action, the feedback loop stops. However, for “on-the-loop” human involvement, the soldier supervises the AI-enabled system. He or she can stop it at any time, but ultimately the machine makes decisions by itself and executes the operation.

³³ Priems and Gizewski, “Leveraging Artificial Intelligence for Canada’s Army,” 41.

Both are quite different and have inherent strengths and weaknesses.³⁴ In horizons 1 and 2, a human in the loop is more likely in most AI-enabled technologies as it involves less risk. However, during horizon 2, a human “on-the-loop” will become more common as the trust in AI and ML evolves. Furthermore, Morgan et al. argue that “international competition could encourage countries to rush the development of artificial military intelligence without sufficient attention to safety, reliability, and humanitarian consequences.”³⁵ Not just competition between adversaries but significant events could have the same impact. The current war in Ukraine could be an excellent example of that statement. If Ukraine or Russia were desperate, would they be ready to fast forward certain safety thresholds of AI to ensure their survival? To ask the question is to answer it.

That being said, it is likely that Canada, the US, and their allies “will require human operators to maintain positive control in its employment” in AI-enabled technologies procured and implemented at the operational and tactical levels in horizons 1 and 2.³⁶ For this reason, it will be used as a consideration for selecting AI applications in chapter 4.

³⁴ Morgan et al., *Military Applications of Artificial Intelligence*, 121.

³⁵ Ibid., 121-122.

³⁶ Ibid., 123.

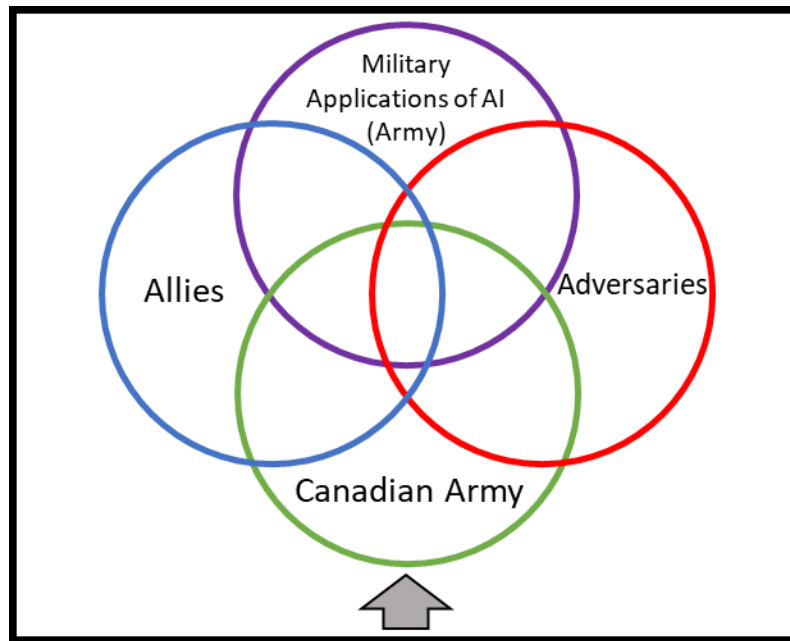


Figure 5. Literature Review's Framework – Canadian Army

Source: Created by author.

In this second section of the literature review, what has been written on AI and ML from a Canadian Army perspective will be analyzed, with a specific focus on finding answers for the second secondary research question: what is Canada's strategic military framework on AI and are there any considerations, constraints, or limitations specific to the Canadian Army that could influence the adoption or development of a particular function or type of AI? This section will be divided into two parts. First, the Canadian Army strategic framework will be dissected to understand how AI-enabled applications can support the modernization priorities of Canada's Army. Afterward, the second

section will focus on articles written by Canadian Army professionals and academics that discuss directly or indirectly what AI can and should achieve for Canada's Army.

To begin with, it is essential to mention that there is no Canadian Armed Forces or Canadian Army strategy specifically regarding AI. As Christian H. Breede argues in an unpublished article and a presentation he gave to the Centre for International and Defence Policy at Queen's University in Kingston, Ontario,³⁷ "there is an acute gap [in Canada] between the development of the [AI] technology and the policies in place to optimize that technology."³⁸ He adds that Canada, being silent on defence and security issues in his AI policies, is potentially "hobbling potential innovations and opportunities."³⁹ This means that there is no clear path on where the CAF and the CA want to go regarding the development of AI-enabled military applications. For a researcher to understand what the Canadian Army needs, one of the only ways, if not the only one, is to investigate doctrine and articles written by academics and practitioners. That is what will be done in the following paragraphs.

Strong, Secure, Engaged: Canada's Defence Policy

Before analyzing Canadian Army strategies and doctrine, it is essential to quickly discuss the overarching Canadian defence strategy, described in *Strong, Secure, Engaged: Canada's Defence Policy*, published in 2017. In this 113-page document, AI is

³⁷ The Center for International and Defence Policy, "Dr. H. Christian Breede: The Bleeding Edge of War."

³⁸ Breede, "The Bleeding Edge of War," 1.

³⁹ Ibid.

not mentioned once. However, deep learning, autonomous systems, and autonomous vehicles are mentioned once each, while the concept of data analytics is referred to twice.⁴⁰ In fact, most of what is written about AI, ML, or related technologies, is in one paragraph of chapter 4 (Global Context) under the sub-section of “Rapid Evolution of Technology.” Below is the integrality of this paragraph:

Technological developments point to a future of defence that is expected to be vastly different than today, with a greater emphasis on information technologies, data analytics, deep learning, autonomous systems, advancements in the electromagnetic and cyber domains, as well as a range of transformative technologies, from quantum computing to synthetic biology. Any number of these advances has the potential to change the fundamental nature of military operations. The rapid pace of technological change will also require that domestic and international legal and governance systems adapt in an effective and timely manner.⁴¹

It is interesting to note that SSE was published the same year as the *Pan-Canadian AI Strategy* but barely mentions AI-related concepts other than its acknowledgment as an emerging technological development. More noticeable is that out of the 111 new initiatives announced or confirmed in SSE, none is related to AI and ML. Therefore, it is fair to say that there is an AI gap in Canadian defence policy.

Close Engagement

For Canadian Army doctrine, there are two important capstone publications to understand where the CA is heading in horizons 1 and 2: *Close Engagement, Land Power*

⁴⁰ Canada, Department of National Defence, *Strong, Secure, Engaged: Canada's Defence Policy* (Ottawa, ON: Canadian Armed Forces, 2017), 55, 77, <http://dgpaapp.forces.gc.ca/en/canada-defence-policy/docs/canada-defence-policy-report.pdf>.

⁴¹ Ibid., 55.

in an Age of Uncertainty, written in 2019 and *Advancing with Purpose: The Canadian Army Modernization Strategy*, written in 2021. The first one, commonly referred to as *Close Engagement*, is the capstone operating concept of the Canadian Army for horizon 2, which is focused approximately 10 to 15 years from the date of the publication (2029-2034). In other words, it is a “conceptual model of how the CA should be configured, equipped, and trained in the medium term.”⁴² It aims at ensuring “that Army capability development proceeds in a purposeful and coherent manner across the capability components—doctrine, organization, training, materiel, leadership, personnel, facilities and interoperability—to deliver this conceptual model.”⁴³

Specifically on AI, ML, or any directly related concept, *Close Engagement* is almost silent. In fact, “Artificial Intelligence” is stated once and human-machine pairing twice. Here is the direct quote that discusses AI in a section titled “Human Dimension: Developing Soldiers and Leaders”:

Artificial intelligence is likely to become ubiquitous and more capable of rendering automated and autonomous decisions. Lethal systems that can operate autonomously will continue to be fielded for specific applications, such as defence against indirect fire, but the most likely advances in capability over the next 20 years will involve human-machine pairing. That concept will bring new cognitive and psychological challenges. On the positive side, the next cohorts will likely be more educated and informed, and technology will be more prominent as an enabler to assist, facilitate and accelerate cognition, knowledge and understanding.⁴⁴

⁴² Department of National Defence, *Close Engagement*, 8.

⁴³ Ibid.

⁴⁴ Ibid., 26.

Even if *Close Engagement* is scarce about AI, this paragraph provides a lot of insight. First, it acknowledges that lethal autonomous weapon systems (LAWS) will be present on the battlefield, giving the example of protection against indirect fire. Second, it emphasizes the human-machine teaming aspect of AI that was also highlighted in many sources analyzed in the first theme of this literature review. Third, by saying that “the next cohorts will likely be more educated and informed, and technology will be more prominent as an enabler to assist, facilitate and accelerate cognition, knowledge and understanding,”⁴⁵ it briefly describes the importance of trust and education for effectively using AI, then the importance of the technology to enhance cognition, knowledge, and understanding.

Furthermore, *Close Engagement* describes five critical areas of focus where future enhancements and modernization efforts should be focused upon. These key areas, or concepts, are connectivity, agility, adaptability, integration, and robustness.⁴⁶ Without going into too much detail here, these concepts are certainly a good base for developing criteria to answer the primary research question and give recommendations on AI's most promising functions for the Canadian Army. More will be discussed about these criteria in chapter 3.

Leveraging Artificial Intelligence for Canada's Army

In this vein, the previously mentioned *Canadian Army Journal* article by Priems and Gizewski discusses precisely how artificial intelligence should meet the requirements

⁴⁵ Department of National Defence, *Close Engagement*, 26-27.

⁴⁶ Ibid., 20-21.

listed in *Close Engagement*. In their own words, their paper “examines the potential impacts of AI on the realization of *Close Engagement*, identifying areas where the application of AI holds the prospect of enhancing the Army’s operational effectiveness.”⁴⁷

The number of applications mentioned in this article, and listed by operational functions, are numerous. Four of them are directly derived from the priorities of *Close Engagement*:

1. Decision-making aid. As the authors explain, *Close Engagement* “requires versatile personnel, adaptable equipment, organization and processes, and an ability to develop shared understanding.”⁴⁸ AI and ML-enabled technologies are perfect for analyzing a large amount of data in the current “data-overload” world, so there is no doubt that this application of AI is central for meeting the military objectives forecasted in horizons 1 and 2.

2. Protection of network. In *CE*, it states that “high-capacity networks able to operate over long distances offer a significant advantage.”⁴⁹ To enable these networks, Priems and Gizewski suggest that AI could be harnessed to protect these critical networks that are becoming more and more important on today’s battlefield: “By offering the prospect of developing algorithms capable of guarding against network failure, electronic warfare and cyberattack, AI may serve to more fully ensure that the Army is capable of

⁴⁷ Priems and Gizewski, “Leveraging Artificial Intelligence for Canada’s Army,” 41.

⁴⁸ *Ibid.*, 43.

⁴⁹ Department of National Defence, *Close Engagement*, 38.

‘reap(ing) the network’s advantages,’ and thereby conduct operations in a more secure, coordinated and collaborative manner.”⁵⁰ This application of AI seems central to the CA of the future and is also mentioned in US Army publications, which will be discussed later in the next section of this chapter.⁵¹

3. Soldier Capability (more precisely the development of immersive digital environments and tools for enhancing cultural understanding). The authors are correct in writing that CE puts a lot of emphasis on the human dimension, especially for the improvement through modernization of human performance and well-being.⁵² They mention several applications of AI, but the ones that seem the most promising and aligned to CE are the development of immersive digital environments, which fall into the added function of training and simulation, and different other applications aimed at enhancing the soldier cultural understanding. More precisely, the authors suggest that AI-enabled language applications, sentiment analysis by data mining of social networks,

⁵⁰ Priems and Gizewski, “Leveraging Artificial Intelligence for Canada’s Army,” 44.

⁵¹ At least two US Army publications discuss the importance of using AI in protecting networks in the future operational environment. They will be discussed later in this literature review, but they are U.S. Army Training and Doctrine Command (TRADOC), TRADOC Pamphlet 525-3-1, *The U.S. Army in Multi-Domain Operations 2028* (Fort Eustis, VA: TRADOC, December 2018); Future Warfare Division, Directorate of Concepts, *Future Study Plan 2019*.

⁵² Priems and Gizewski, “Leveraging Artificial Intelligence for Canada’s Army,” 45; talking about: Department of National Defence, *Close Engagement*, 26-28.

facial and name recognition could enhance the soldier's capability in a complex environment.⁵³

4. Control of overall logistics capability. Another application directly linked to the CE objective is that "control of overall logistics capability must be centralized at formation level."⁵⁴ Priems and Gizewski suggest that predictive maintenance, intelligent supply chain management, and autonomous delivery systems could help meet this objective.⁵⁵ Sustainment being closer to what the industry is currently using than kinetic effects part of the Act operational function, there is no doubt that AI-enabled sustainment technologies are to be explored in all horizons, but more specifically in the short term as most of these technologies exist in a form or another.

Another critical aspect of Priems and Gizewski's article is that they suggest constraints, restraints, and limitations in developing and using AI-enabled technologies that the CAF and Canadian Army should follow. First, they mention the requirement for oversight over AI technologies to make sure that the machine decision-making process is not opaque so it can be trusted by commanders and staff officers alike. They recommend the creation of "AI advisors" as a branch, which is an interesting idea in itself.⁵⁶ Second, they mention how "human-machine teaming represents a cornerstone for AI development

⁵³ Priems and Gizewski, "Leveraging Artificial Intelligence for Canada's Army," 45.

⁵⁴ Department of National Defence, *Close Engagement*, 46.

⁵⁵ Priems and Gizewski, "Leveraging Artificial Intelligence for Canada's Army," 48-49.

⁵⁶ *Ibid.*, 43.

and operationalization and maximizing the strengths of the human and machine while minimizing the shortcomings of each, is central to its effectiveness.”⁵⁷ In other words, AI-enabled technology needs to be built to increase trust over time, so soldiers can get more used to working with machines throughout their careers. Third, AI-enabled technology, and more specifically the ones that have important lethal or non-lethal effects, have to comply with the laws of armed conflicts (LOAC) and within strong ethical standards: “Any view to employment of such systems must be based on high confidence that they will perform as intended and on the understanding that such use would only occur within established ethical and legal parameters (e.g. the LOAC).”⁵⁸ This means that AI-enabled technologies must comply with LOAC and the Army ethos in all their applications, lethal or not. Fourth, autonomous systems should not be fully autonomous. According to them, a human needs to stay “in-the-loop” or “on-the-loop” at a minimum.⁵⁹ This restraint aligns with almost all reviewed literature analyzed in this study.

In summary, Priems and Gizewski’s article highlights essential considerations that will be directly used in this thesis. It proposes four applications directly aimed at achieving *Close Engagement*’s objectives and suggests four limitations in developing and using these technologies. These four applications and four limitations will be used in chapter 4 for answering the primary research question.

⁵⁷ Priems and Gizewski, “Leveraging Artificial Intelligence for Canada’s Army,” 46.

⁵⁸ Ibid.

⁵⁹ Ibid.

Advancing with Purpose

The second essential CA publication to analyze is *Advancing with Purpose: The Canadian Army Modernization Strategy*. As its title suggests, this publication is the modernization strategy of the CA and an action plan for modernizing the force for horizons 1 and 2, but with a stated focus on the short term of horizon 1.⁶⁰ The chapter on “Implementation” is significant for this research as the priorities of tasks in modernizing all aspects of DOTMLPF-P⁶¹ are clearly stated. More specifically, line of effort 4.5 is of primary importance as it mentions the priorities of research and development in AI and other emergent or disruptive technologies. Here is what it says verbatim about AI:

While COS A Strat will enable the institution through an increasingly deliberate approach to amassing data and exploiting it to make decisions, it is the Canadian Army’s responsibility to examine the potential of AI and machine data to transform some aspects of land operations, including exploiting data and information to produce intelligence and predictive modelling to support decision-making.⁶²

This paragraph states precisely some functions of AI and ML. It gives relevancy to this research but also mentions two potential applications: produce intelligence and produce modelling to support decision-making. These could be functions to select and compare for further data analysis in chapter 4.

⁶⁰ Department of National Defence, *Advancing with Purpose*, 26.

⁶¹ DOTMLPF-P is the acronym commonly used for discussing the different domains of Force Management in the US Army, which are doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy. For more details, see: Headquarters, Department of the Army, Army Regulation 71-32, *Force Management – Force Development and Documentation Consolidated Policies* (Washington, DC: Army Publishing Directorate, March 2019).

⁶² Department of National Defence, *Advancing with Purpose*, 52.

Now, here is what is written on robotics and autonomous systems:

Autonomous systems can already perform many dull, dirty, and dangerous tasks but also have incredible potential to expand their utility, including their ability to operate collaboratively with humans creating a system in which the sum of the parts is greater than the whole. The requirement for a human in or on “the loop” will remain for any application of lethal force but their utility to assist with sensing and sustaining are already apparent.⁶³

This paragraph clearly states the restraint of having a human “in or on the loop” for lethal force application. As this modernization strategy is binding, this limitation will be used when choosing AI functions for detailed analysis and ranking in chapter 4.

Additionally, *Advancing with Purpose* lists six foundational modernization principles to guide modernization efforts for the foreseeable future. Each of them will be summarized below (the complete definitions are in appendix A):

1. Digitization and enhanced networking:

Future networks must be designed and implemented to enhance shared understanding, the speed of decision-making, and the effectiveness of command and control. ... Failure to exploit these networks or, conversely, become entirely dependent on them, has potential risks that may negate an advantage or even leave the Canadian Army at a significant disadvantage. Further, emerging advances in artificial intelligence, such as its use within predictive planning tools, has the potential to greatly shorten the decision-action cycle. ... Society is on the edge of burgeoning artificial intelligence and other digitally-driven technologies. ... The Canadian Army must harness data and embrace digital culture to benefit from their potential and act as a shield from the negative aspects of new technologies.⁶⁴

2. One Army.

Only *One Army* will be able to manage the array of concurrent operational demands. The Regular Force, ARes, CR, and the civilian work-force will be a single operating entity. The full integration of the Regular and Reserve components, and capability in particular, will be achieved where the optimum

⁶³ Department of National Defence, *Advancing with Purpose*, 52.

⁶⁴ *Ibid.*, 26-27.

capacity of each component will enable meeting the readiness and operational output demands of the future.⁶⁵

3. Interoperable.

Interoperability with multiple organizations is vital for the way Canada prepares, trains, and fights. It is required across the full spectrum of joint, interagency, multinational, and public interactions. In the pan-domain fight, joint interoperability is indispensable. The Canadian Army will also achieve interoperability with key ABCANZ and NATO allies. Further, the Canadian Army will be able to work alongside UN or coalition partners when required.⁶⁶

This principle seems particularly relevant as it is a common theme across virtually all CA publications and academic articles reviewed in this research. It highlights the importance of having this principle as a criterion in data analysis.

4. Simplicity.

Technology must absolutely be leveraged to assure military superiority, but the Canadian Army's approach, systems applications, and methodology must preserve simplicity. In all, we will embrace "usability or ease of use" where the perspective and needs of the user are prioritized. Simplicity is the key to effective maintenance and equipment use.⁶⁷

5. Adaptive Dispersed Operations (ADO) Ready.

As detailed in *Close Engagement*, the Canadian Army will prepare for ADO as a baseline and way of operating.²³ The principles and deductions contained in *Close Engagement* are to be understood and incorporated by all Canadian Army members.⁶⁸

It is worth noting that this principle fuses the concepts of close engagement (the doctrine, not the publication) and of adaptive dispersed operations (ADO) that was initially

⁶⁵ Department of National Defence, *Advancing with Purpose*, 27.

⁶⁶ Ibid.

⁶⁷ Ibid.

⁶⁸ Ibid.

brought forward in *Land Operations 2021 – Adaptive Dispersed Operations – The Force Employment Concept for Canada’s Army of Tomorrow*, published in 2007.⁶⁹

6. Versatility.

The Canadian Army will seek to develop and acquire capabilities that achieve the widest utility across both domestic and expeditionary environments, thus achieving the most efficient use of funds. This approach will also guarantee equipment familiarity across a diverse set of mission tasks.⁷⁰

These six principles summarize the critical considerations in modernizing the Army for years to come, including the development, acquisition, and use of AI-enabled technologies. For this reason, they will be used as a framework for comparing and ranking the AI applications identified in this study, which will be explained in more detail in chapter 3, Methodology.

⁶⁹ Canada, Department of National Defence, *Land Operations 2021 – Adaptive Dispersed Operations – The Force Employment Concept for Canada’s Army of Tomorrow* (Kingston, ON: Directorate of Land Concepts and Design, 2007), https://publications.gc.ca/collections/collection_2009/forces/D2-188-2007E.pdf.

⁷⁰ Department of National Defence, *Advancing with Purpose*, 27.

Main Ally (United States)

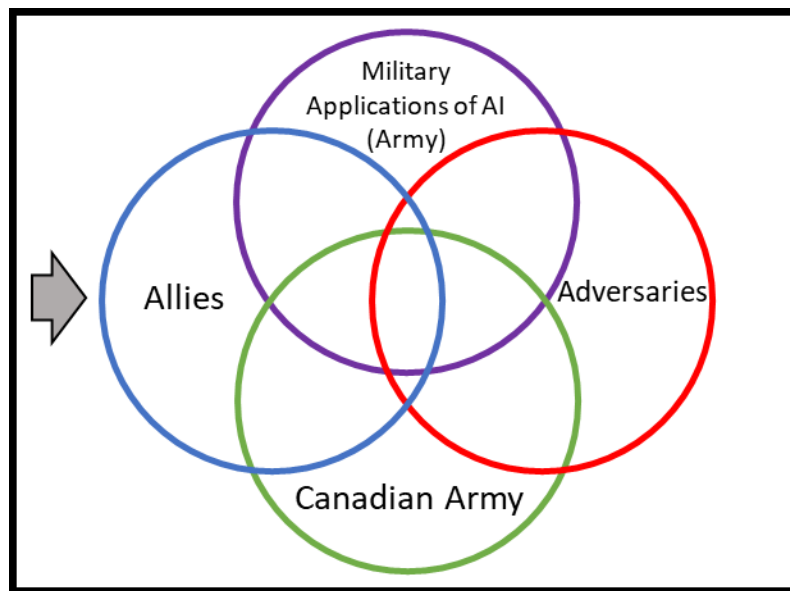


Figure 6. Literature Review's Framework – Allies

Source: Created by author.

At the beginning of this research, the intent was to look at what Canada's main allies were doing to find the most promising functions of AI for land warfare. It was the rationale for researching the last secondary research question (what are our main allies and adversaries currently predicting and focusing on?) To begin with, the United States, the United Kingdom, and France were researched and looked at. However, for lack of time and to narrow the scope of the research, it was decided to only focus on the United States for three reasons. First, they are Canada's closest ally by far. Therefore, understanding what the US Army is doing in AI and ML is fundamental to maintaining interoperability and effectiveness in fulfilling the CAF core missions of defending Canada, North America as part of NORAD, and leading and contributing to NATO and

other US-led coalition efforts.⁷¹ Second, according to virtually all indexes found for this research, they are the global leader in Artificial Intelligence.⁷² Third, according to most qualitative and quantitative metrics, they have arguably the most powerful military globally, including in total Defense spending.⁷³ More importantly, they have been the western world leader in developing and implementing new military technologies since World War II. According to Colin Gray, in a critical essay of the famous Russell F. Weigley's *The American Way of War*, developing and using new technologies and being dependent upon them is actually part of the American way of war.⁷⁴ Last but not least, the number of American sources on the subject is abundant and easy to access for the author of this thesis, who is studying in the US Army Command and General Staff College at the moment of this writing.

In this literature review, the focus will be on analyzing what the United States Army is currently focusing and working on in AI and ML to inform what functions of AI should be further explored in chapter 4. For this to be achieved, this section will be divided into three parts: (1) AI as seen in the Multi-Domain Operations (MDO) capstone

⁷¹ Department of National Defence, *Strong, Secure, Engaged*, 81-82.

⁷² Tortoise Media, "The Global AI Index."

⁷³ The United States was the first in highest military expenditure in 2020 by more than 500 billion dollars in front of the second, China. However, in spending as a share of GDP (%), they are not in first position. For more details, see: Diego Lopes Da Silva, Nan Tian, and Alexandra Marksteiner, *Trends in World Military Expenditure, 2020* (Solma, Sweden: Stockholm International Peace Research Institute, April 2021), https://sipri.org/sites/default/files/2021-04/fs_2104_milex_0.pdf.

⁷⁴ Colin Gray, "The American Way of War: Critique and Implications," in *Rethinking the Principles of War*, ed. Anthony D. McIvor (Annapolis, MD: Naval Institute Press, 2005), 29-30.

document; (2) operationalization of AI to achieve MDO according to the Army Futures Command and the 2020 Army AI Strategy; (3) and an analysis of how a few scholars think AI can be used in MDO.

To understand where the United States Army is heading in implementing AI at the operational and tactical level, it is paramount to understand the foundational doctrine and way of battle that the organization is using to modernize. This doctrine is Multi-Domain Operations (MDO), described and explained in a pamphlet written by the Training and Doctrine Command (TRADOC) in December 2018. Titled *The U.S. Army in Multi-Domain Operations 2028*, the document aims at laying the foundations for how the US Army will fight adversaries and enemies in the future, more precisely with a vision span up to 2028 as described in the title.⁷⁵ General Mark A. Milley, Chief of Staff of the Army at the time of the pamphlet's publication, explains what the Army wants to achieve with this capstone document:

Strategic competitors like Russia and China are synthesizing emerging technologies with their analysis of military doctrine and operations. They are deploying capabilities to fight the US through multiple layers of stand-off in all domains – space, cyber, air, sea, and land. The military problem we face is defeating multiple layers of stand-off in all domains in order to maintain the coherence of our operations. Therefore, the American way of war must evolve and adapt. *The U.S. Army in Multi-Domain Operations, 2028* is the first step in our doctrinal evolution. It describes how US Army forces, as part of the Joint Force, will militarily compete, penetrate, dis-integrate, and exploit our adversaries in the future.⁷⁶

TP 525-3-1 defines the concept in these terms:

Operations conducted across multiple domains and contested spaces to overcome an adversary's (or enemy's) strengths by presenting them with several operational

⁷⁵ TRADOC, TRADOC Pamphlet 525-3-1, 5.

⁷⁶ Ibid., i.

and/or tactical dilemmas through the combined application of calibrated force posture; employment of multi-domain formations; and convergence of capabilities across domains, environments, and functions in time and spaces to achieve operational and tactical objectives.⁷⁷

Something that this definition does not explicitly say is that MDO is the US Army's answer to a switch in focal point from the 20 years of counterinsurgency in the Middle East to today's peer adversaries, Russia and, most importantly, China. Therefore, MDO seek to close the gap between China and Russia in perceived adversarial advantages that these two nations developed while the United States focused on Iraq and Afghanistan. To name a few, MDO explains how the US Army can separate itself from the competition in information warfare and in long-, mid-, and short-range systems, like hypersonic missiles, to give an often-cited example. The central idea of MDO is summarized this way in *The U.S. Army in Multi-Domain Operations 2028*:

Army forces, as an element of the Joint Force, conduct Multi-Domain Operations to prevail in competition; when necessary, Army forces penetrate and dis-integrate enemy anti-access and area denial systems and exploit the resultant freedom of maneuver to achieve strategic objectives (win) and force a return to competition on favorable terms.⁷⁸

This research does not have the pretention, or the will, to describe MDO in more detail.⁷⁹ However, it is essential to understand how the US Army wants to fight in the future to analyze how AI and ML fit in this equation. Before moving to how the US Army plans to operationalize AI in MDO, it is relevant to note what was written on AI in

⁷⁷ TRADOC, TRADOC Pamphlet 525-3-1, GL-7.

⁷⁸ Ibid., 17.

⁷⁹ For those who want to dig further on this topic, the MDO Logic chart, which summarizes the key ideas of the TRADOC pamphlet, is included in Appendix B of this thesis. It is directly taken from TRADOC Pamphlet 525-3-1, v.

this 2018 pamphlet. In this 100-page document, “artificial intelligence” is written six times, “machine learning” one time, and the word “autonomous” two times. More specifically, three main functions of AI in support of MDO were mentioned. First, AI and ML are seen as one of the most important, if not the most, for high-speed data processing for enabling decision-making in an operational environment contested in all domains and where speed is the competitive advantage.⁸⁰ Second, AI is seen as the way to converge sensors across all domains to “complicate enemy deception and obscurity through automatic cross-cueing and target recognition.”⁸¹ Third, this pamphlet sees AI playing a role in precision logistics by forecasting sustainment needs and using autonomous unmanned systems (i.e. ground- or air-based drones) for battlefield deliveries.⁸² In summary, TRADOC Pamphlet 525-3-1 does not give a lot on how the United States predicts the use of AI in the future but still provides a foundation for other works, as it will be demonstrated in the following pages.

The most relevant source that discusses the operationalization of AI in the US Army in horizons 1 and 2 is an Army Futures Command’s document published in 2019 titled *Future Study Plan 2019 – Operationalizing Artificial Intelligence for Multi-Domain Operations*. Written by Nikolai Andresky and Major Adam Taliaferro about eight months after the TRADOC pamphlet discussed above, it aims at providing “frameworks for employing AI to help the Army and Joint Force better define required capabilities and the

⁸⁰ TRADOC, TRADOC Pamphlet 525-3-1, 20.

⁸¹ Ibid., 38.

⁸² Ibid., GL-8.

associated data and network architecture to enable multi-domain capable forces.”⁸³

Furthermore, with the help of five realistic vignettes, it discusses potential and promising applications of AI and ML for all warfighting functions. Six of them are particularly relevant to this study:

1. Conduct information collection and analysis to increase situational understanding (MDCOP).
2. Enable rapid, informed, and sound decision-making.
3. Lighten the warfighter’s cognitive workload to increase overall effectiveness.
4. Detect, identify, and penetrate high-risk areas with unmanned systems.
5. Attack the enemy’s anti-access/aerial denial (A2/AD) networks.
6. Improved sustainment throughput.⁸⁴

A few of these functions are directly in line with what was found in the Canadian Army-centered literature review, like increasing situational understanding, improving sustainment throughput, and enabling more rapid and well-informed decision-making. However, because of a difference in capabilities and focus between the Canadian and United States armies, AI and ML to penetrate high-risk areas and attack anti-access and anti-denial (A2AD) systems are mostly unique to the US Army.

Another important publication to analyze in this literature review is the *2020 Army Artificial Intelligence Strategy*, which goes hand-in-hand with the previously analyzed publication by Army Futures Command. This US Army AI Strategy published

⁸³ Future Warfare Division, Directorate of Concepts, *Future Study Plan 2019*, i.

⁸⁴ Ibid., iii-iv, 7-14.

only a year ago is an essential document for understanding and comparing what the US Army is currently predicting and working on. It provides a timeline of implementation up to 2035 with clear steps and milestones to achieve the Army strategy (see figure 7).

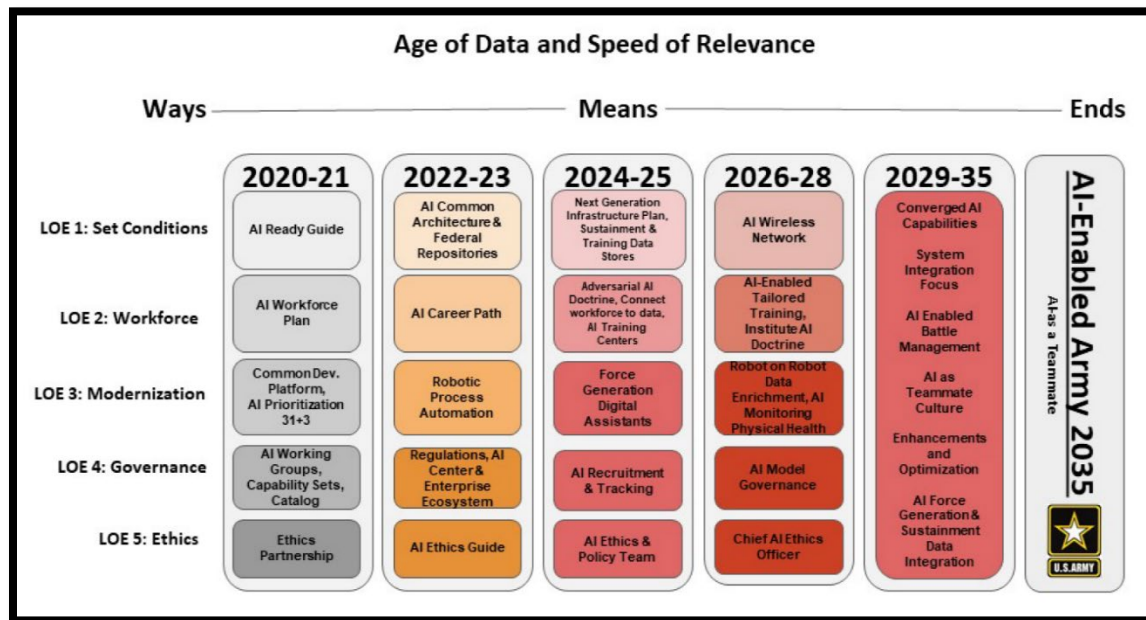


Figure 7. US Army AI Lines of Effort and Implementation Timeline

Source: Headquarters, Department of The Army, *2020 Army Artificial Intelligence Strategy* (Washington, DC: Government Printing Office, January 2021), 4.

In summary, the *2020 Army Artificial Intelligence Strategy* states five objectives to establish the foundation for the so-called “AI-Enabled Force: “(1) delivering AI-enabled capabilities that address key missions; (2) scaling AI’s impact across DoD through a common foundation that enables decentralized development and experimentation; (3) cultivating and leading the Army's AI workforce; (4) engaging with commercial, academic, and international allies and partners; and (5) leading in military

ethics and AI safety.”⁸⁵ Another interesting concept discussed in length in this strategy is the “emergence of robots working together in groups with Soldier-machine teaming,”⁸⁶ which is a common theme with the Canadian Army’s vision on AI and ML. While this strategy does not give much on potential AI-enabled functions or applications, its vision up to 2035 is relevant in informing what is realistically possible and planned for horizons 1 and 2.

Now that the key departmental publications have been analyzed, it is time to examine what some scholars have to say on the application of AI in MDO. First, Dr. Dan G. Cox from the School of Advanced Military Studies (SAMS) has written an article on this exact topic titled “Artificial Intelligence and Multi-Domain Operations: A Whole-of-Nation Approach Key to Success.” In this article from the *Military Review*, the author summarizes a few students’ monograph’s key considerations and restrictions to render AI applicable to MDO in horizons 1 and 2. Summarizing and adding to articles written by SAMS students, he brings particularly interesting and unique considerations on the question of trust,⁸⁷ which reinforce what Priems and Gizewski discussed in their *Canadian Army Journal* article. Here is a quote that summarizes a few original concepts on the idea of trust between humans and AI-enabled technologies:

Maj. Bobby Monday notes that trust is one of the key factors preceding the effective use of AI in a U.S. Marine Corps formation like a Marine air ground

⁸⁵ HQDA, *2020 Army Artificial Intelligence Strategy*, 2.

⁸⁶ Ibid.

⁸⁷ Dan G. Cox, “Artificial Intelligence and Multi-Domain Operations: A Whole-of-Nation Approach Key to Success,” *Military Review* 101, no. 3 (May-June 2021): 80-84, <https://www.armyupress.army.mil/Journals/Military-Review/English-Edition-Archives/May-June-2021/Cox-AI-MDO/>

task force. He argues that this trust bridge can only be built through constant schooling, training, and developing and interacting with AI programs and platforms.⁸⁸

The U.S. military partnered with Google to develop an AI algorithm [called Maven] to help sift through targeting data to find viable military targets in the conflict with the Islamic State. ... Despite Maven's improvement at identifying targets, U.S. Air Force Gen. Mike Holmes says he does not trust the system yet. Holmes wants Maven to improve significantly before he will trust the targeting data it provides. This is not an unsound position to take, but the problem is that military commanders are unlikely to reach a point where “significant improvement” actually assuages their concerns.⁸⁹

Cox continues his argument on trust by explaining that the problem has three ramifications, which are the following:

First, there must be a degree of explainability regarding what the AI is doing. Second, AI, in some ways, should be regarded as a potential trust agent or AI can never really be used in the true mission command sense of a battlefield agent. Third, the U.S. military, along with the United States as a nation, must decide whether AI can be trusted with lethality.⁹⁰

This idea of trust is fundamental in understanding which AI-enabled functions are likely to be employed in horizons 1 and 2. Even if the technology exists, which is the case for most AI-enabled applications discussed so far, they will not be used if they are not trusted. This specific point is of particular importance for informing the findings of this thesis. For this reason, “build trust between soldiers and AI-enabled machines” will be a comparison criterion added to the modernization principles in data analysis (see chapter 3 for more details).

⁸⁸ Robert Monday, “Artificial Intelligence: Expected to Win; Ready to Fail,” (Monograph, School of Advanced Military Studies, US Army Command and General Staff College, 2018).

⁸⁹ Cox, “Artificial Intelligence and Multi-Domain Operations,” 80-81.

⁹⁰ Ibid., 81.

Another interesting source for this section of the literature review is an article by Colonel Simon Poudrier, a Canadian Royal Air Force officer. He attended the National Defence University in Washington, DC in a program focused on the industry of emerging technologies, including Artificial Intelligence. In an article published in the *Canadian Army Journal* titled “Leveraging Allies Regarding Artificial Intelligence: The Critical Link between the Commercial and the Defence Industry,” the author brings a different lens on the development of AI-enabled technologies. As a senior Canadian officer studying in the United States, he points out interesting multinational considerations in developing military AI at the strategic level that also impacts potential AI-enabled functions at the operational and tactical levels.⁹¹ Based on his research, Poudrier offers a few recommendations summarized in this paragraph:

The US has built a commanding lead with respect to the commercial civilian application of AI through its global firms, but it may be at the same level as other countries, such as China, regarding its military application. AI sources its power in the successful use and analysis of large, validated data, which virtually everyone produces every day through the use of the Internet of Things. China is ‘knocking on Europe’s door,’ as well as the rest of the world, with tomorrow’s network technology to power the IoT. It is simultaneously offering a large marketplace for economically struggling countries. ... The US would therefore strongly benefit by cooperating with its long-time allies to develop a *common* and *ethical* AI technology, and strengthen its efforts in developing the applicability of the AI industry for the defence sector.⁹²

In other words, Poudrier argues that interoperability and data sharing between the United States military and its “long-time allies” would benefit not just the military alliances like

⁹¹ Colonel Simon Poudrier, “Leveraging Allies Regarding Artificial Intelligence: The Critical Link between the Commercial and the Defence Industry,” *Canadian Army Journal*, 20, no. 3 (Summer 2020): 38-45, <http://www.journal.forces.gc.ca/Vol20/No3/PDF/CMJ203Ep38.pdf>

⁹² *Ibid.*, 44.

NATO or NORAD but also the United States. If its network of allies is the competitive advantage of the US military in comparison with China, it needs to be extended to the development of military AI-enabled technologies. According to the author, it starts with sharing data, building interoperable systems, and the open contribution of industries and universities.⁹³ This argument reminds the one of Kissinger, Schmidt, and Huttenlocher in *The Age of AI: And Our Human Future*. These three authors also advocate for allies to contribute together to avoid a nation being so far behind in using AI that they would be irrelevant on the world stage.⁹⁴ It is also a similar discourse that Imbrie et al. advocate in a CSET report titled *Agile Alliances: How the United States and Its Allies Can Deliver a Democratic Way of AI*.⁹⁵

One more important consideration highlighted by the literature review was the promising application of the Joint All-Domain Command and Control (JADC2) concept. Interestingly, this US Air Force idea of system of systems is as relevant for MDO as it is for ADO and the ideas brought forward by *Close Engagement*. Ultimately, it could be a bridge between these two doctrines, which are significantly aligned conceptually,⁹⁶

⁹³ Poudrier, “Leveraging Allies Regarding Artificial Intelligence,” 38-45.

⁹⁴ Kissinger, Schmidt, and Huttenlocher, *The Age of AI*, 135-176.

⁹⁵ Andrew Imbrie, Ryan Fedasiuk, Catherine Aiken, Tarun Chhabra, and Husanjot Chahal, *Agile Alliances: How the United States and its Allies Can Deliver a Democratic Way of AI* (Washington, DC: Center for Security and Emerging Technology, Georgetown University, February 2020), <https://cset.georgetown.edu/wp-content/uploads/CSET-Report-Agile-Alliances-1.pdf>.

⁹⁶ Patrick J.G. Perron, “Pan-Domain Operations: How Can the Canadian Army Prepare its Forces and Contribute to Multi-Domain Coalitions?” (Service paper, Canadian Forces College, 2021), 5, <https://www.cfc.forces.gc.ca/259/290/23/192/Perron.pdf>.

according to Lieutenant Colonel Patrick J. G. Perron in a service paper from the Canadian Forces College (CFC). According to him, JADC2 seeks to “turn information into knowledge, decisions and action faster than the enemy” by leveraging AI, automation, and decision-making tools.⁹⁷ In other words, JADC2 is one of the US Air Force’s attempts to compete against China and Russia, particularly against their A2AD systems, in a multi-domain fight by converging joint and multinational sensors and information into a centralized system that would facilitate commanders’ decision-making. It is how the US and their allies can get the decisive information advantage necessary to compete against peer adversaries. Similarly to the US Army Project Convergence,⁹⁸ AI and ML are central to the JADC2 concept as they can minimize “data overload” by making sense of what is important, urgent, and all in-between. Perron argues that the CAF and CA must follow the US military current rapid modernization if they want to stay relevant, and it starts by embracing the concepts of MDO and JADC2.⁹⁹ Here are the three recommendations particularly relevant to this study:

Aggressively pursue interoperable digital technologies and artificial intelligence to be able to “plug-in” US multi-domain formations, develop shared situational awareness, and fasten the decision-action cycle.

Leverage all opportunities to train with US and allied multi-domain formations, align doctrine, and modernize the CA simulation training system to account for pan-domain activities and effects.

⁹⁷ Perron, “Pan-Domain Operations,” 3.

⁹⁸ Colin Demarest, “Project Convergence reinforces the need for shared standards across the services,” *C4ISRNET*, last modified February 23, 2022. <https://www.c4isrnet.com/battlefield-tech/it-networks/2022/02/23/project-convergence-reinforces-the-need-for-shared-standards-across-the-services/>.

⁹⁹ Perron, “Pan-Domain Operations,” 7-8.

Train land forces in degraded cyber, electronic warfare and space environments. Train mission command to the threshold of failure by nurturing a culture of learning and innovative thinking. Evolve the CA culture from combined arms to joint, pan-domain and digital.¹⁰⁰

Perron's service paper reinforces the importance of interoperability with our allies and, more specifically, with the US military. He believes interoperability is paramount in doctrine, communication systems, networks, and data sharing. Furthermore, he argues that the CA needs to find ways to contribute to MDO. Lastly, he reinforces the importance of using AI to facilitate decision-making through the ultra-fast convergence of information. These conclusions are all relevant to this research.

In summary, these reports, publications, and articles reinforce the importance of the criteria of "interoperability" in comparing AI-enabled functions. Interoperable, not only between joint services, but also with multinational partners, specifically with the United States as Canada's most important ally and the current world leader in AI. This is why the criteria of "interoperability" will be used as a comparison criterion. Additionally, this section of the literature review proved that MDO and ADO are compatible and surprisingly similar, which means they mutually reinforce each other. Finally, all sources agree that AI and ML can and should be used to converge sensors and information to facilitate decision-making in a complex battlefield where the information could become the most important advantage. These three conclusions will all be used for data analysis in chapter 4.

¹⁰⁰ Perron, "Pan-Domain Operations," 7.

Main Adversaries (China and Russia)

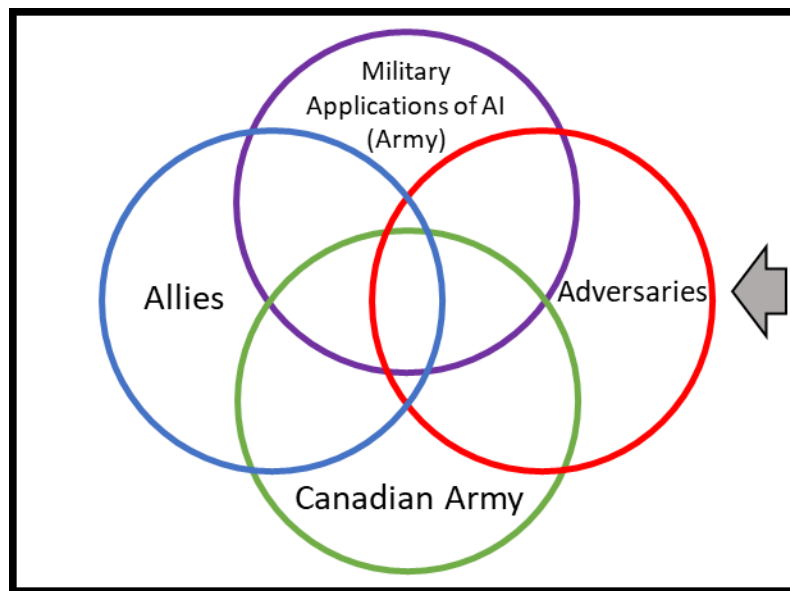


Figure 8. Literature Review's Framework – Adversaries

Source: Created by author.

One more step is required for completing this literature review. Answering the second half of the last secondary research question: what are our main adversaries currently predicting and focusing on? To do that, Canada and the United States' two main adversaries will be looked upon: China and Russia. Others were considered when starting this research, like North Korea and Iran. However, early in reviewing the literature, it is evident that China is the only real competitor to the US in the development and use of AI military technologies, and Russia is also working hard at operationalizing AI and ML for military applications, particularly in their involvement in Syria, and more recently, in Ukraine. For these reasons, and for time's sake, China and Russia were chosen to be studied further.

In the following few pages, China will be analyzed first, then Russia. For the latter, the war in Ukraine was raging at the time of this writing, so a few Ukraine articles were used to inform this literature review. However, due to the extreme difficulty of finding facts in the ocean of propaganda and information operations on both sides, and the lack of perspective on current events, only what was directly relevant and somewhat verifiable was used. Other researchers will have the time and leisure to study the use of AI and ML in Ukraine when the war is over.

China

As Morgan et al. explain in *Military Applications of AI*, “The United States faces significant international competition in artificial military intelligence.”¹⁰¹ And the most significant competitor is undoubtedly China. They are comfortably in second place on the Tortoise *Global AI Index*,¹⁰² and multiple authors argue that they might be at the same level as the United States in military AI. Cox, previously cited, is one of these authors: “America's major adversaries are pursuing the weaponization of AI at breakneck speed in an effort to balance, and perhaps surpass, current U.S. asymmetric advantages on the battlefield. Among America's adversaries, China is at the forefront of both AI development and the weaponization of AI.”¹⁰³ More specifically, Cox argues that China has an advantage over the US military with the “fusion of efforts between the civilian and

¹⁰¹ Morgan et al., *Military Applications of AI*, 119-120.

¹⁰² Tortoise Media, “The Global AI Index.”

¹⁰³ Cox, “Artificial Intelligence and Multi-Domain Operations,” 88.

military sectors”¹⁰⁴ and in the China Communist Party’s (CPP) “ready access to any data generated by Chinese corporation.”¹⁰⁵ Data being one of the keys to AI, as stated multiple times during this research, the CPP has a competitive advantage that cannot be underestimated. Similarly, Poudrier says that the United States is in advance regarding civilian applications of AI, “but it may be at the same level as other countries, such as China, regarding its military application.”¹⁰⁶

Yet, what does this mean in terms of AI and ML applicability at the operational and tactical level? What functions of AI is the Chinese military currently pursuing? It is what Fedasiuk, Melot, and Murphy, amongst other things, describe in a recent report from the Georgetown University-based Center for Security and Emerging Technology (CSET) titled *Harnessed Lightning: How the Chinese Military is Adopting Artificial Intelligence*. They have analyzed AI contracts and procurement records recently published by the People’s Liberation Army (PLA) and state-owned defence enterprises, which led to a better understanding of what they are currently pursuing. Here are the findings directly related to AI-enabled functions in land warfare:

The PLA seems most focused on procuring AI for intelligence analysis, predictive maintenance, information warfare, and navigation and target recognition in autonomous vehicles.

Whereas some PLA officers have expressed serious reservations about developing lethal autonomous weapons systems (LAWS), laboratories affiliated with the Chinese military are actively pursuing AI-based target recognition and fire control research, which may be used in LAWS. ...

¹⁰⁴ Ibid., 84.

¹⁰⁵ Cox, “Artificial Intelligence and Multi-Domain Operations,” 85.

¹⁰⁶ Poudrier, “Leveraging Allies Regarding Artificial Intelligence,” 44.

The PLA hopes to use AI to generate asymmetric advantages vis-à-vis the United States, which it regards as a “strong enemy” (强敌), but also a role model for AI development. ...

The PLA is stepping up investment in information operations and adaptive radar systems to jam and blind U.S. sensor and information networks, which PLA leaders judge to be particularly vulnerable.”

To compensate for vulnerabilities in its own networks, the PLA may adopt edge applications of AI (directly proximate to or embedded within a platform) that can operate semi- or fully autonomously.¹⁰⁷

A few deductions can be extrapolated from these findings. To begin with, there are similarities with what AI-enabled functions Canada and the United States are currently predicting and working on. The most prominent are adaptive radar systems, big data intelligence analysis, predictive maintenance, sensor jamming capabilities, and target recognition. There are also significant differences in what is pursued. The most important are surveillance systems, information operations tools, and target recognition in autonomous or semi-autonomous vehicles. It could be argued that the first and last ones are most likely being researched by the “five eyes” militaries as well, but not necessarily to the same extent as China. Surveillance being a part of society in the People’s Republic of China (PRC), it makes sense that they are leaders in AI-enabled surveillance systems. It is also what Gregory C. Allen concludes in his analysis of China’s AI strategy: “China

¹⁰⁷ Fedasiuk, Melot, and Murphy, *Harnessed Lightning*, iii-iv.

is currently making extensive use of AI in domestic surveillance applications”¹⁰⁸ and “China already exports armed autonomous platforms and surveillance AI.”¹⁰⁹

This last quote from Allen brings the interesting case of autonomous platforms, which Fedasiuk, Melot, and Murphy also mention, and with more emphasis by Elsa B. Kania in a Brookings Institution and CSET partnership report called “‘AI Weapons’ in China’s Military Innovation.” She highlights Chinese investments in AI and ML, then gives a few interesting operational and tactical level AI-enabled technologies that the PRC is currently pursuing: robotics, swarming, and, more importantly, autonomous systems. Indeed, she explains that “advances in weapons systems described or advertised as ‘autonomous’ (自主) or ‘intelligentized’ (智能化) have built upon existing strengths in the research and development of unmanned (无人) systems and missile technology.”¹¹⁰ She seems worried about this trend, but also mentions that “it is encouraging that Chinese military scientists and researchers are starting to debate and engage with safety issues and technical concerns, as well as legal and ethical considerations.”¹¹¹

¹⁰⁸ Gregory C. Allen, *Understanding China’s AI Strategy: Clues to Chinese Strategic Thinking on Artificial Intelligence and National Security* (Washington, DC: Center for a New American Security, February 2019), 6.

¹⁰⁹ Ibid., 5.

¹¹⁰ Elsa B. Kania, “‘AI Weapons’ in China’s Military Innovation,” (Brookings Institution and Center for Security and Emerging Technology, Georgetown University, Washington, DC, April 2020), 1, https://www.brookings.edu/wp-content/uploads/2020/04/FP_20200427_ai_weapons_kania_v2.pdf.

¹¹¹ Ibid.

In summary, China seemed just behind or on par with the United States for the current use and development of AI-enabled military technologies. Like the US, they pursue AI-enabled applications like radar systems, high-volume intelligence analysis software, decision-making enablers, predictive sustainment and target recognition technologies. Yet, they are also putting more effort into developing surveillance, information warfare, and autonomous systems because they see weaknesses in the US grasp of information operations and their use of radar sensors. What seems interesting is that Russia also emphasizes information operations, which will be described in the following paragraphs.

Russia

Unlike their Chinese ally, Russia does not have such a strong economy and technology sector. In the Tortoise “Global AI Index,” they are in the 32nd position, not too far from Italy, the United Arab Emirates, and Malta. In this ranking, they struggle with talent, research, and development indicators, way behind the US, China, and several NATO countries.¹¹² It is also what a 2021 translated report from a Russian AI think tank argues by saying that the Russian AI industry is lagging relative to other countries and should increase research spending and funding by three or five times.¹¹³ In their own words, “As of 2020, Russia has not been among the AI leaders and has been noticeably

¹¹² Tortoise Media, “The Global AI Index.”

¹¹³ National Technology Initiative (NTI) Competence Center for Artificial Intelligence at the Moscow Institute of Physics and Technology (MIPT), *Artificial Intelligence Almanac: 2020 Index Report*, ed. Ben Murphy, trans. Etcetera Language Group, Inc. (Moscow: NTI MIPT, December 2021).

lagging in most AI areas. Russia's AI-related R&D is lagging most of all."¹¹⁴ However, this report shows that the AI sector is dynamic and has had a few success stories in the last few years. Recent events in the United States, Syria and Ukraine also demonstrated that Russia is particularly aggressive in seeking military and information dominance via cyber and information warfare.

These findings are directly in line with Edmonds et al. in a publication titled *Artificial Intelligence and Autonomy in Russia*. In this report from the Center for Naval Analyses (CAN) that relies on open-source material in Russian, the authors highlight that the Russian military is currently focusing on the dominance of the information domain on the battlefield. They are pursuing AI-enabled technologies, "such as information management for decision-making and autonomy,"¹¹⁵ and tools for conducting information operations.¹¹⁶ The use of a "deepfake" video in March 2022 at the beginning of the invasion of Ukraine is an excellent example of Russia using AI-enabled technologies for disinformation. This video, posted on social media and a Ukrainian TV channel website via a defacing hacking effort, showed Vladimir Zelensky, the Ukrainian President, "asking Ukrainians to lay down their arms"¹¹⁷ in a press conference setting. The video was quickly identified as fake and ridiculed by Ukraine authorities. However,

¹¹⁴ NTI MIPT, *Artificial Intelligence Almanac: 2020 Index Report*, 77.

¹¹⁵ Edmonds et al., *Artificial Intelligence and Autonomy in Russia*, iii.

¹¹⁶ *Ibid.*, 82-84.

¹¹⁷ Tom Simonite, "A Zelensky Deepfake Was Quickly Defeated. The Next One Might Not Be," *Wired*, March 17, 2022, <https://www.wired.com/story/zelensky-deepfake-facebook-twitter-playbook/>.

it is still a perfect example of how Russian-backed hackers can use AI for information operations. As argued by the author of this magazine article, this may be an example of a trend in the future as AI-enabled deepfakes (pictures, audio clips, videos, etc.) are improving and becoming closer to reality each day.¹¹⁸

Another interesting source is an article from *War On The Rocks* written by Margarita Konaev and Samuel Bendett. It explains how Syria has been a testing ground for the Russian Army to experiment with their latest technologies, including autonomous and AI/ML-enabled weapon systems. The most noteworthy functions of AI discussed in this article are the following:

The Nerehta unmanned vehicle is supposedly a test-bed for military AI applications. ...

Connection of all the national early warning radars as well as anti-aircraft and anti-missile systems like S-300 and S-400 into a single “armored fist”—and that AI will assist in analyzing information all these systems receive for much faster decision-making in times of crisis. ...

AI-enabled automated control system will connect offensive and defensive airborne and stationary assets in Crimea—aircraft, helicopters, missile batteries, and other systems—for optimal data analysis and decision-making. ...

Russia’s [...] Advanced Research Foundation announced that it will design an AI-enabled system to sift through vast quantities of satellite imagery for faster and more accurate analysis. ...

“Harnessing the power of AI,” as former Deputy Defense Minister Yuri Borisov stated in March 2018, will allow Russia to more effectively contest the information environment and win in cyber wars. ...

¹¹⁸ Simonite, “A Zelensky Deepfake Was Quickly Defeated. The Next One Might Not Be.”

Russia is also likely to capitalize on breakthroughs in AI, big-data analytics, and machine learning to conduct more targeted, scalable, and impactful information operations.¹¹⁹

To summarize, Russia focuses on similar technologies to the US and China. Still, it is likely to focus on the information domain as it is one of its priorities in all aspects of its military instrument of power. This seems to be a pattern between China and Russia that does not surprise but is still of particular importance for this research.

Summary

In summary, several deductions can be pulled from this literature review. First, the primary research question of this research has not been studied before from this point in time and from a Canadian Army perspective. Therefore, this study is unique in its primary research question and methodology. Second, the criteria for analyzing the data in chapter 4 has been found in *Close Engagement*, the CA modernization strategy in the form of the modernization principles. Third, from Priems and Gizewski's article, four limitations have been identified for selecting the applications that will be analyzed further to provide final recommendations. Fourth, sufficient primary and secondary sources have been found to answer the third secondary research question from the United States, Russia, and China's perspectives. The main takeaways for data analysis are that interoperability and trust are fundamental for implementing AI-enabled technologies in horizons 1 and 2 and that China and Russia, in addition to seeking to develop similar technologies to Canada and the United States, are also seriously pursuing the

¹¹⁹ Konaev and Bendett, "Russian AI-Enabled Combat Coming to a City Near You?"

development of autonomous weapons systems, surveillance technologies, and tools to maximize the effectiveness of their information operations. Fifth, comparison tools have been used to do qualitative research on AI and ML but are not usable in their current form for this research due to their unique nature. A new comparison method will have to be built based on existing tools. More will be explained in chapter 3, Methodology.

CHAPTER 3

RESEARCH METHODOLOGY

Introduction

In this chapter, each aspect of the methodology will be explained so future researchers can replicate the methods used in this study. First, an overview of the methodology will be presented, then the data collection, analysis methods, and instruments will be justified and explained in detail. The literature review has informed the best methodology to use with the limitations and delimitations identified in the introduction.

Before explaining the methodology in detail, here is a reminder of the primary and secondary research questions:

Primary: using a ranking system to predict the ability to impact the Canadian Army operations, what functions of Artificial Intelligence should the Canadian Army pursue with 5 and 15-year timeframes (horizons 1 and 2)?

Secondary:

1. What forms and functions of AI have the most potential military application within horizons 1 and 2?
2. What is Canada's strategic military framework on AI and are there any considerations, constraints, and/or limitations specific to the Canadian Army that could influence the adoption or development of a specific function or type of AI?
3. What are our main allies and adversaries currently predicting and focusing on?

Method

This research will use a qualitative methodology and more specifically the case study method. This specific method will be used because it is best suited for developing an in-depth analysis of a subject from multiple varied sources. It is assessed as the best technique to predict the functions of AI in the future due to its flexibility and reliance on several data sources.¹²⁰ The case studies used will be ten AI-enabled functions that will be described at the beginning of chapter 4. They will then be compared against the six modernization principles described in the literature review, plus the one of “build trust between soldiers and AI-enabled machines.” The result will be a ranking of the most promising functions of AI, which will be used to answer the primary research question, hence providing recommendations to decision-makers on what the CA should focus on within the next 15 years.

Figure 9 below summarizes the sequence and steps of the methodology used in this thesis. Steps 1 and 2 have been executed in previous chapters and will be confirmed in this one, while steps 3 to 10 will be executed in chapters 4 and 5.

¹²⁰ Spurlin, “Qualitative Research.”

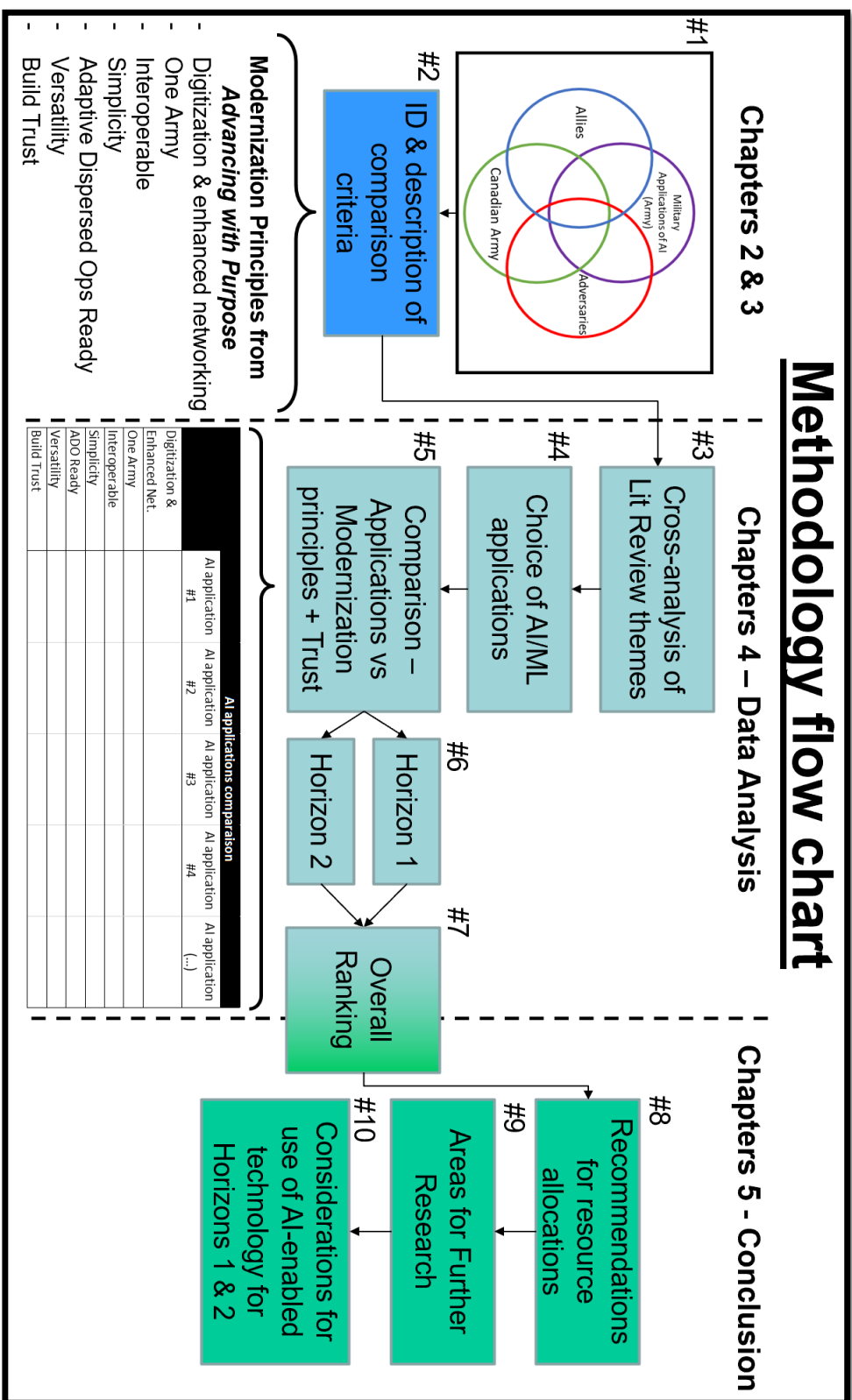


Figure 9. Methodology Flow Chart

Source: Created by author.

Data Collection

The author of this research will be the main data collection instrument throughout the research. The data collected was mainly written in nature, but was diversified as much as possible in types, forms, languages, and provenance. Most of the sources used were governmental publications from military organizations and otherwise; reports from different university research organizations and think tanks; articles from military or strategic oriented academic journals; and books directly or indirectly related to the topic of AI and ML. However, with the civilian information technology sector being the lead on the world stage for AI research, a few articles were found in academic journals that have nothing to do with the military arts and sciences. For example, a lot has been done in AI on autonomous vehicles, games, and business supply chains. These sources were used as they also apply to the military as described by a few authors, including Poudrier in his analysis of the AI industry.¹²¹ A few articles on the historical context of emergent technologies and military revolutions were also used for putting the emergence of AI and large scale combat operations (LSCO) environment in context. A few multimedia sources were also used, mostly videos.

As stated above, an important aspect of data collection for this research, more specifically for the third secondary research question (what our allies and adversaries are currently predicting and focusing on), was the use of articles and government publications (military doctrine, future projections, defence policies, etc.) coming from the United States for allies. Before discussing our adversaries, it is important to remind that

¹²¹ Poudrier, “Leveraging Allies Regarding Artificial Intelligence.”

the United States have been selected because they are unquestionably our closest military ally and the world leader in AI, as demonstrated by the Tortoise Media AI index.¹²² Furthermore, they are the most powerful military globally, and they have been leaders in implementing new technologies in the last century, as explained in the literature review.

For our adversaries, China and Russia were the countries analyzed for apparent reasons. They are our main adversaries and potential enemies as demonstrated in recent geopolitical events in the United States European Command (US EUCOM) and the United States Indo-Pacific Command (US INDOPACOM) area of responsibilities. Furthermore, they have the resources needed to compete and even surpass NATO countries in the arm race of AI, including the United States. As the author of this study does not speak Mandarin or Russian, only primary and secondary sources translated into English were used, which is clearly a limitation of this study. Words count and a qualitative approach was used to highlight the key considerations and main AI-enabled functions that our adversaries are currently predicting and focusing on.

Data Analysis

For data analysis, the modernization principles as described in *Advancing with Purpose* and discussed in the literature review (see literature review and Appendix A) was chosen as criteria for comparing the selected applications. As a reminder, they are the following: digitization and enhanced networking; one Army; interoperable; simplicity; adaptive dispersed operations (ADO) ready; and versatility.¹²³ Weighted

¹²² Tortoise Media, “The Global AI Index.”

¹²³ Department of National Defence, *Advancing with Purpose*, 26-27.

numerical were used to make a comparison between the different forms of AI and their assessed potential for impacting the Canadian Army operations in each of horizons 1 and 2. The inspirations for this comparison tool are stage 3 of the Canadian Operational Planning Process (OPP) and step 5 of the Military Decision Making Process (MDMP): COA Comparison.¹²⁴ The measuring scale is composed of five score options: -1, -0.5, 0, 0.5, and 1. These scores represented the potential to impact the Canadian Army operations in horizons 1 and 2:

Table 3. Measuring Scale Used for Comparing AI-Enabled Applications

Score	Assessed impact on CA operations
-1	Very low chance of impacting the CA operations
-0.5	Low chance of impacting the CA operations
0	Neutral chance of impacting the CA operations
0.5	High chance of impacting the CA operations
1	Very high chance of impacting the CA operations

Source: Created by author.

Other data analysis methods were used in the study. For the third secondary question aimed at analyzing what our allies and adversaries are forecasting and working on, the thematic analysis and quantitative descriptive analysis methods were used. Recurring themes or ideas were compiled in a working document, then illustrated in tables. The same was done with number counts of recurring words describing military

¹²⁴ Headquarters, Department of the Army, Field Manual 6-0, *Commander and Staff Organization and Operations* (Washington, DC: Army Publishing Directorate, May 2014), 137-139.

applications of AI. Using these data analysis methods highlighted what nations are discussing the most in their official publications.

Crucial to this thesis, a subjective analysis by the author was required to assess what forms of AI seem the most promising and relevant at the tactical and operational level for the CA. In other words, the AI applications used for comparison purposes were selected by the author based on criteria informed by the literature review. The most stated and promising AI applications were used, plus a minimum of one for each operational function. To this point, it is assessed from the literature review that all aspects of land warfare can benefit from AI-enabled technologies.¹²⁵ Therefore, dismissing an operational function could be detrimental to what this study aims to achieve, hence the importance of selecting a representative sample of all operational functions. Furthermore, some had to be selected at the best knowledge of the author based on relevance, the potential for decisive use in both horizons, and the specific four Canadian Army limitations identified in chapter 2 (minimal opacity; human-machine trust building; adherence to LOAC and the Army ethos; and no “fully autonomous” AI systems in battlefield effects producing systems). The final results were ranked to directly answer the primary research question: using a ranking system to predict the ability to impact the Canadian Army operations, what forms of Artificial Intelligence should the Canadian Army pursue with 5 and 15-year timeframes (horizons 1 and 2)? They were then compiled in tables similar to tables 4 and 5.

¹²⁵ Priems and Gizewski, “Leveraging Artificial Intelligence for Canada’s Army,” and Future Warfare Division, Directorate of Concepts, *Future Study Plan 2019*, provide the most significant argument for the usefulness of AI and ML in all operational and warfighting functions.

Table 4. Table Used for Comparing AI-Enabled Applications

	Application #1	Application #2	Application #3	Application #4	Application #5	Application #6	Application #7	Application #8	Application #9	Application #10
Digitization & Enhanced Net.										
One Army										
Interoperable										
Simplicity										
ADO Ready										
Versatility										
Build Trust										
Total	0	0	0	0	0	0	0	0	0	0

Source: Created by author.

Table 5. Table Used for Ranking of AI-Enabled Applications to Pursue in Horizons 1 & 2

Ranking	AI Application	Score
1	Application x	
2	Application y	
3	Application z	
4	Application a	
5	Application b	
6	Application c	
7	Application d	
8	Application e	
9	Application f	
10	Application g	

Source: Created by author.

Ethical Considerations

As this study was conducted with the initial close collaboration of CALWC, potential bias, and pressure to come to certain conclusions could be in play. Like any organization, they have known and unknown biases, opinions, and agendas for future capabilities. Artificial Intelligence and Machine learning are not exceptions to this rule. It was paramount to use their help and guidance without losing sight of the research

process, particularly during data collection, data analysis, and conclusion. For the researcher to stay true to research ethics principles, third parties and members of the committee were used.

Summary

In short, this research is qualitative in nature and is using the case studies method. Data collection included all types of sources from different nations and languages, which highlighted some limitations for data collection of Russian and Chinese documents. For data analysis, particular attention was given to the selection of ten AI-enabled applications based on the limitations, considerations and factors informed by the literature review. Of great importance for the relevance of this study, the *Advancing with Purpose* modernization principles and the concept of “trust between soldiers and AI-enabled machines” were chosen as the criteria to compare the ten most promising AI-enabled applications, which ultimately led to answering the primary research question.

Finally, even if no human subjects were used for this research, ethical considerations exist. They were mitigated by deliberately using a third-party and the research comity to avoid excessive subjectiveness. Now that the problem has been framed, the literature has been reviewed and the methodology demonstrated, it is finally time to execute the core of the research: data collection and analysis.

CHAPTER 4

ANALYSIS

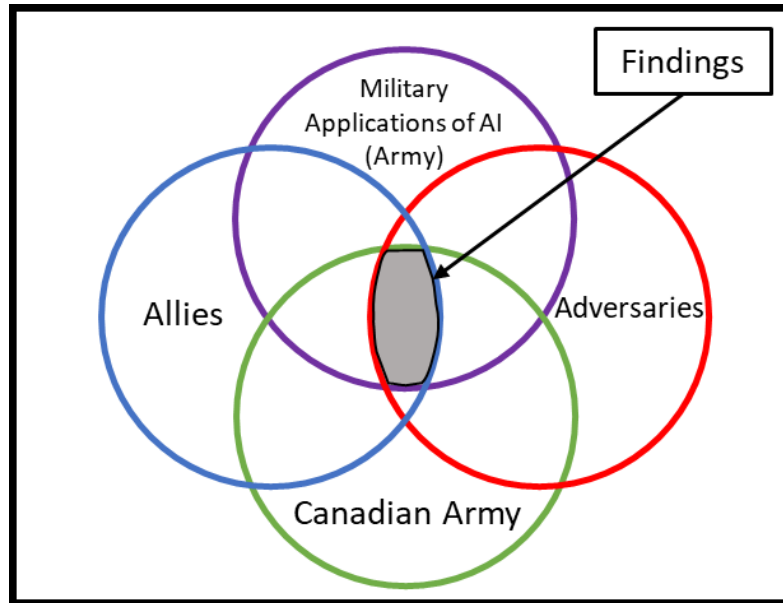


Figure 10. Findings

Source: Created by author.

As a reminder, the primary research question is: using a ranking system to predict the ability to impact the Canadian Army operations, what functions of Artificial Intelligence should the Canadian Army pursue within a 5 and 15-year timeframes (horizons 1 and 2)? This chapter aims at answering this question to inform Canadian Army decision-makers, key staff and Defense Team members working on modernization and future concepts to facilitate prioritization and focus resources.

The findings below are organized into three parts as described in the methodology. First, the analysis begins with the choice of ten functions of AI used for

further comparison and an explanation of why they were chosen. Second, it continues with a comparison of the selected functions against the modernization principles found in *Advancing with Purpose*, plus the one of trust. Third, the ranking that emerged from the comparison will be analyzed and explained to extract concrete recommendations.

AI-Enabled Applications Selection

To focus the research, a choice had to be made between the applications or functions of AI discussed in section 1 of the literature review (see figure 1). A few considerations highlighted in chapter 2 were considered to make this choice. First, four limitations identified by Priems and Gizewski were used to select the AI-enabled applications.¹²⁶ If an application was not conforming to these limitations, it was not selected:

1. Requirement for oversight over AI technologies to minimize opacity.
2. AI-enabled technology needs to be built to increase trust over time.
3. Compliance with the laws of armed conflicts (LOAC) and Canadian Army ethos.
4. Human needs to stay “in-the-loop” or “on-the-loop” at a minimum.

Second, as detailed in chapter 3, a minimum of one AI-enabled application per operational function was selected as it is assessed from the literature review that all aspects of land warfare can benefit from AI-enabled technologies. Third, the Canadian Army lacks specific key capabilities like air defence or medium-range anti-tank weapons, to give a few examples. Therefore, the CA is not in an excellent position to lead research

¹²⁶ See the literature review for more details on these limitations.

on these technologies. It can be assumed that the US is already far in front of Canada in research, so it can be assumed they would share the technology with their closest allies (5EYES, NORAD, etc.) if needed and in both nation's interests. This consideration was not enough to discard an AI-enabled application from being compared, but it did play a role in executing the analysis and providing final recommendations. Fourth, similar to the Canadarm and its role in space exploration,¹²⁷ potential Canadian niches that might align well with national expertise and values were considered. As a medium power, Canada has had to develop niches in military and international matters to keep a competitive edge on the global stage.¹²⁸ AI would be an excellent way to explore a new niche in military and civilian technologies, with multiple benefits for the industry and Canadian society.

Now that the restrictions and considerations have been identified and described, the ten selected AI-enabled functions that will be used for comparison, categorized by operational functions, are the following, with an explanation for each:

¹²⁷ "The Canadarm was a remote-controlled mechanical arm, also known as the Shuttle Remote Manipulator System (SRMS). During its 30-year career with NASA's Space Shuttle Program, the robotic arm deployed, captured and repaired satellites, positioned astronauts, maintained equipment, and moved cargo." From: Karl H. Doetsch, Garry Lindberg, Laura Neilson, and Erin James-Abra, "Canadarm," The Canadian Encyclopedia, last modified March 18, 2022, <https://www.thecanadianencyclopedia.ca/en/article/canadarm>.

¹²⁸ The Canadarm, peacekeeping missions and the CF-105 Arrow program are a few good examples.

High-Frequency Wargame Simulator

This AI-enabled technology most likely already exists in some forms or is currently being developed. For example, Schwartz et al. have published a paper titled “AI-enabled Wargaming in the Military Decision-making Process,” that precisely discusses this function and provides examples in a US Army context.¹²⁹ To the researcher’s knowledge, this technology is not being used in the CA at the moment. Therefore, a Canadianized version would be required if used by the CAF to simulate specific Canadian Army’s capabilities against any threat in different simulated operational environment. This application was chosen for data analysis because it is directly in line with Adaptive dispersed operations (ADO) principles, and it is potentially an excellent way of speeding up commanders’ decision-making, which is one of the CA and US Army modernization priorities as discussed in the literature review. Furthermore, wargaming is an event in OPP and MDMP that tends to be biased and even sometimes emotional; having AI-enabled wargaming systems would minimize biases and emotions, which would optimize performance and execution on the battlefield.

Friendly and Enemy Course of Action (COA) Generator

In a similar fashion to wargame simulators, COA generators may already be in some development phase in military research-focused organizations. Captain William T.

¹²⁹ Peter J. Schwartz, Daniel V. O’Neill, Meghan E. Bentz, Adam Brown, Brian S. Doyle, Olivia C. Liepa, Robert Lawrence, and Richard D. Hull, “AI-enabled Wargaming in the Military Decision-making Process,” *Proceedings* 11413 (2020), <https://doi.org/10.1117/12.2560494>.

DeBerry, to give an example, has recently built an AI-enabled wargame method as part of his thesis at the Air Force Institute of Technology.¹³⁰ It could take years to build a tool that would be good enough to be trusted by corps, division, brigade, or battalion commanders. However, the potential is immense for this application in horizons 1 and 2, as COA development during OPP, MDMP, or other types of planning methodologies is often biased and lengthy. This application was chosen because “decision-making aids” were cited by virtually all sources reviewed and have the potential of meeting the aspiration of ADO and MDO at least in horizon 2, if not sooner.

Sense

Imagery Analysis Platform, Including Tools Focused on Identifying Visual Disinformation (Deepfake, etc.)

AI-enabled technologies already exist to analyze imagery and are being used daily by different civilian and military organizations/agencies.¹³¹ Imagery analysis is one of the most, if not the most, frequently quoted AI-enabled technology in the literature. Therefore, it needs to be part of the final comparison and ranking, as it will continue to grow and be more ubiquitous from now to the end of horizon 1. Furthermore, it checks all the boxes of AI modernization considerations: it builds trust in AI systems; it is easily interoperable; it is ethical if appropriately used; it fits all future modernization doctrines; and it would integrate perfectly in a JADC2 system of systems. As defined in this

¹³⁰ William T. DeBerry, “The Wargaming Commodity Course of Action Automated Analysis Method,” (Master’s thesis, Air University, 2021), <https://scholar.afit.edu/etd/5041>.

¹³¹ Cox, “Artificial Intelligence and Multi-Domain Operations.”

research, this function also includes video analysis tools like the ones used to identify disinformation or other information operations launched by adversaries. The literature review specifies that the information domain is a western world weakness that China and Russia undoubtedly want to exploit.¹³² For these reasons, it could become a niche for the Canadian Army as fighting disinformation fits well with Canadian values and current societal trends in the country.

Cultural and Sentiment Understanding

As suggested by Priems and Gizewski, “data mining of social networks and open sources to determine relationships, plans, patterns of life, and to confirm events, as well as the use of sentiment analysis to determine the specific or general feelings of a population upon explicitly stated feelings, or through non-verbal behaviours”¹³³ could be a function of AI in ADO. This potential function of AI was selected to be one of the ten because it is an application that responds well to the challenges of the future land operating environment.¹³⁴ Furthermore, it could be a niche for the Canadian Army as the CAF has often excelled in understanding different cultures and working with them during peacekeeping and capacity building operations.

¹³² See literature review for more details on how China and Russia intend to exploit the information domain.

¹³³ Priems and Gizewski, “Leveraging Artificial Intelligence for Canada’s Army,” 45.

¹³⁴ Department of National Defence, *Close Engagement*, 11-14.

Act

Electromagnetic Spectrum (EMS) AI-enabled Technology to Jam, Blind, and Deceive the Enemy

This function was inspired by the movement and maneuver vignette of *Future Study Plan 2019: Operationalizing Artificial Intelligence for Multi-Domain Operations*¹³⁵ and by Priems and Gizewski's article.¹³⁶ "Act" is a particularly sensitive operational function due to the questions of trust and ethics. No official policies have been published on AI's lethal and kinetic use; therefore, only non-kinetic functions were considered. This offensive EMS application was ultimately chosen because it is directly in line with the multi-domain priorities required to prevail against future adversaries like China and Russia, as forecasted in MDO.¹³⁷ Used correctly and in coordination with other effects in multiple domains, it would efficiently generate operational and tactical dilemmas to the enemy, which would enable movement and maneuver effects executed by any land forces. Furthermore, it has the potential to build trust over time for offensive applications of AI yet by diminishing the risk to force.

Shield

Protection of Networks (Cyber & EMS)

Someone could argue that this function is too broad compared to the others selected. It is somewhat true, but the following quote from *Close Engagement* made the

¹³⁵ Future Warfare Division, Directorate of Concepts, *Future Study Plan 2019*, A-9 - A-11.

¹³⁶ Priems and Gizewski, "Leveraging Artificial Intelligence for Canada's Army," 46.

¹³⁷ TRADOC, TRADOC Pamphlet 525-3-1, 6-7.

difference in making this decision in the end: “As communications and information systems continue to merge, it is likely that, in the near future, the conceptual boundary between cyberspace activities and EW will disappear.”¹³⁸ In the 15 years covered by this research, they will most likely be fused together, so separating it would have caused more confusion. With decision-making tools and imagery analysis, this function is one of the most cited, potentially because it is already employed or on the verge of being used on a larger scale. Hence, it was a “must-have” for data analysis and comparison.

Semi-Autonomous Perimeter Air-Defense (GBAD)

Even if this capability is currently non-existent in the Canadian Army and the US Army has an enormous advance in everything “air defence,” this application was primarily chosen for three reasons. First, *Close Engagement* clearly states that “an air defence capability or set of capabilities will be needed to protect deployed forces against the following threats: fast attack aircraft; armed helicopters; ballistic missiles; and small, low-altitude, and potentially swarming UASs.”¹³⁹ Second, in the *Defence Investment Plan 2018*,¹⁴⁰ the MND is currently looking to buy air defence capabilities. Third, air defence is potentially where AI is already the most advanced and where it has been

¹³⁸ Department of National Defence, *Close Engagement*, 54.

¹³⁹ *Ibid.*, 45.

¹⁴⁰ Government of Canada, “Ground Based Air Defence,” Defence Capabilities Blueprint, Defence Investment Plan 2018, last modified January 9, 2020, <http://dgpaapp.forces.gc.ca/en/defence-capabilities-blueprint/project-details.asp?id=940>.

implemented the longest.¹⁴¹ Therefore, it is essential to include semi-autonomous perimeter defence in the final comparison.

Sustain

Control of Overall Logistics Capability (Smart Defence Resource Management Information System (DRMIS))

Sustainment is another area where virtually all sources point at as “linkages with civilian advances in AI technology are clearer in the Sustain realm than in the case of other operational functions.”¹⁴² In *Close Engagement*, the MDO capstone publication, and Priems and Gizewski’s article, the tracking and control of logistic functions were highlighted. It was also the case in most of the adversaries’ sources reviewed.¹⁴³ For this reason, it had to be included in this chapter for further analysis and comparison. DRMIS being the system used in the CA, it could be able to predict supply and maintenance needs, then recommend sustainment COAs to the users for optimal throughput in garrison and overseas in any operations.

Drones/Robots for Delivery and Return of Logistics

Another frequently cited function of AI was AI-enabled robots or drones to facilitate resupply and other sustainment activities. This application is particularly

¹⁴¹ For more details on an incident involving a Navy AI-enabled Air Defense system, the Aegis, in 1988 see: Peter W. Singer, *Wired for War: The Robotics Revolution and Conflict in the 21st Century* (New York: Penguin Books, 2009), 124-126.

¹⁴² Priems and Gizewski, “Leveraging Artificial Intelligence for Canada’s Army,” 48.

¹⁴³ See chapter 2 for more details on how most sources assess logistics and sustainment as a priority for AI/ML implementation.

interesting because it could become the test-bed for the use of autonomous or semi-autonomous machines on the battlefield. It is one of the most promising ways of building trust between humans and machines without overwhelming risks. The recent announcement by Elon Musk, Tesla and SpaceX CEO and owner, of his serious engagement in developing a robot that would be used in factories and households, is another sign that a more robotic world is at humanity's doorstep.¹⁴⁴ As described in the previous paragraph, sustainment is one of the most promising and potentially beneficial uses of military AI, which is why it was selected for further analysis.

Training

DATE AI-enabled Enemies and Adversaries Part of an Immersive Digital Environment for Simulation Purposes

As discussed previously in the literature review, the “function” of training was added in this research due to its potential in enhancing training and simulation in the Army. For the last 20 years at least, new technologies have been particularly prominent in simulation and training organizations, as video games have become more popular with the soldiers, and Western militaries have looked for ways to get a competitive advantage on the battlefield. For this research, the chosen application in training and simulation is specifically using Artificial Intelligences (in the video games sense) to act like the Decisive Action Training Environment (DATE) or “real-world” adversaries and enemies

¹⁴⁴ Elon Musk, “A Future Worth Getting Excited About,” TED 2022, April 6, 2022, video of interview, 1:06:28, https://www.ted.com/talks/elon_musk_a_future_worth_getting_excited_about?language=en.

based on their assessed doctrine (Donovia/Russia, Gotland/Belarus, China, Iran, etc.).¹⁴⁵

In other words, realistic AI and ML would be used to compete against human organizations in computer-based exercises. For example, during an Exercise Unified Resolve (Ex UR) or a Joint warfighter assessment (JWA), the enemy would not be played by humans but by an AI replicating the enemies' doctrine and TTP based on the analysis of actual battles and doctrine publications. Similar to what AIs have been doing in the games of chess (AlphaZero), go (AlphaGo), and videogames (Starcraft II),¹⁴⁶ to name only a few examples, they will learn by themselves, adapt to the opposite forces, then compete against the exercised units participating in the exercise. This algorithm could also be used for wargaming, which would offer some economy of effort. This function would be an excellent way to efficiently use what is currently being developed by the industry for military purposes. For these reasons, it will be used for further analysis in this research.

To note, applications in table 6 below were also considered but ultimately left out on purpose for various reasons explained in the right-end column:

¹⁴⁵ The Decisive Action Training Environment (DATE) is a deep and detailed opposing forces scenario and framework used in the Canadian and US Armies. Two good sources are: US Army Training and Doctrine Command, "Date World," OE Data Integration Network, accessed May 1, 2022, <https://odin.tradoc.army.mil/DATEWORLD>; and Headquarters, Department of the Army, Field Manual 7-100, *Opposing Force Doctrinal Framework and Strategy* (Washington, DC: Army Publishing Directorate, 1 May 2003).

¹⁴⁶ Oriol Vinyals, Igor Babuschkin, Wojciech M. Czarnecki, Michael Mathieu, Andrew Dudzik, Junyoung Chung, David H. Choi et al., "Grandmaster Level in StarCraft II Using Multi-agent Reinforcement Learning," *Nature* 575 (October 2019): 352, <https://doi.org/10.1038/s41586-019-1724-z>.

Table 6. Considered Applications Not Used in Final Comparison

Command	
Signal Intelligence Analysis	Not enough time to analyze properly. Imagery analysis was chosen instead as it has more or similar potential in horizon 1.
Virtual personal assistants (VPAs) for Commanders	VPAs like Alexa, Siri, Google, and many others were considered. It was not chosen because a VPA is not precise enough in its application. It can do everything and nothing at the same time as it is more a voice interface, than an AI, at least in its current form.
AI-enabled Political (POLAD) and Legal Advisors (LEGAD)	Was not selected because it was assessed as too narrow and specialized for this study.
Sense	
Sensor convergence for targeting	Not enough time to analyze properly and the US is currently working on JADC2 ¹⁴⁷ and Project Convergence, which is focused on this specific AI-enabled application of sensor convergence. ¹⁴⁸ The CA should continue collaboration with this project as it is highly promising.
Act	
Offensive Cyber	Not in the realm of land warfare. The CA is not responsible for this domain in the CAF.
Semi-autonomous counter-battery fires	Because the CA does not have MLRS and long-range fires capabilities, Canada is not well placed to research this AI-enabled application. It could be used for field artillery as well, but for lack of time it was dismissed from this study.
Shield	
CBRN standoff detection	Not enough time to analyze properly and CBRN is currently not assessed as the most important “shield” application to study in this research as it is not part of our adversaries most likely courses of action (MLCOA).
Semi-autonomous Area defence turrets	It is assessed that the CA is not “ready” to focus on this type of AI-enabled technology for ethical reasons and potential non-compliance with LOAC. Explainability, and trust between soldiers and machines need to be further developed before going forward with this technology.

Source: Created by author.

As explained in the remark column, some of these applications were discarded because they did not meet the selection criteria described at the beginning of this chapter. However, some of them did not make the cut simply due to a lack of time and to ensure

¹⁴⁷ Perron, “Pan-Domain Operations,” 3.

¹⁴⁸ Demarest, “Project Convergence Reinforces the Need for Shared Standards across the Services.”

this thesis does not extend too much. It was assessed that ten applications were the maximum amount to handle.

Comparison and Results Explanation

Armed with the understanding of why these functions of AI were selected, it is now time to discuss the results. Below is the table that summarizes the scores for each AI-enabled application in comparison with the *Advance with Purpose*'s modernization principles, plus the criteria of trust.

Table 7. AI-Enabled Applications Comparison

	Wargame simulator	F & ECOA Generator	Imagery analysis	Cultural understanding	Jam, blind, deceive EMS	Protection of Networks	Semi-Autonomous Perimeter AD	Smart DRMIS	Logistics drones	DATE Simulation
Digitization & Enhanced Net.	1	1	1	1	1	1	1	1	1	0
One Army	1	1	1	1	0.5	1	0.5	1	0.5	1
Interoperable	0.5	0.5	1	1	0.5	0	1	-1	0	0.5
Simplicity	0.5	0	1	-1	0	0	0	0.5	-1	0.5
ADO Ready	1	1	1	1	0.5	1	1	1	1	-0.5
Versatility	-0.5	-0.5	1	0	-0.5	1	-0.5	1	0.5	-0.5
Build Trust	0.5	0.5	1	1	0.5	0	0.5	1	1	0.5
Total	4	3.5	7	4	2.5	4	3.5	4.5	3	1.5

Source: Created by author.

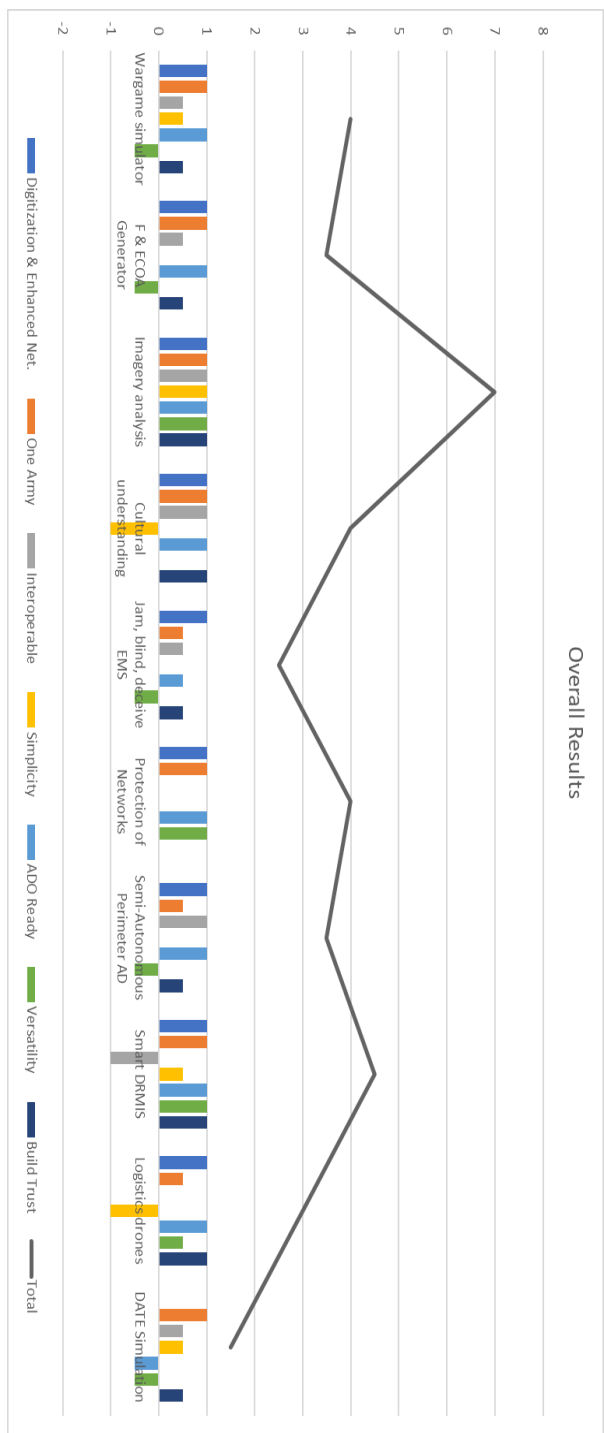


Figure 11. Methodology Flow Chart

Source: Created by author.

To better understand the results, they will be described by modernization principles and criteria to make sense to the reader and be potentially reusable for further research.

Digitization and Enhanced Networking

This criterion only had minimal influence on the overall scores as only one application did not receive a “1.” Almost all the functions received the same score because this modernization principle is directly focused on increasing digitization and network capabilities, which is what these AI-enabled networks would do if implemented. To emphasize this point, this principle is the only one that directly mentions AI in its *Advance with Purpose* definition.¹⁴⁹ Therefore, there is no doubt that these nine applications would significantly increase digitization and enhance networking, so they all received a perfect score. However, what explains that “AI-enabled enemies and adversaries part of an immersive digital environment for simulation purposes” received a neutral score is precisely because the criterion’s definition describes that future modernization efforts should be focused on enhancing digitization and networking in operations, not in training. Having this kind of AI-enabled simulation would undoubtedly contribute to developing better soldiers but would not strengthen digitization and networking in domestic or expeditionary operations. However, it did not receive a negative score because having a “smarter” enemy in training scenarios could help develop more digitally savvy soldiers, trainers, or trainees. As described in the previous section, these AI-enabled DATE adversaries could also be used in wargame simulators or

¹⁴⁹ Department of National Defence, *Advancing with Purpose*, 27.

friendly or enemy COAs generators, which would impact operations. This is why it ultimately received a neutral grade.

One Army

Three applications received “0.5,” and the rest received a perfect grade. It is impossible to know precisely how these new technologies would be implemented. It is even harder to forecast how they would be equally or unequally integrated into the regular force, Army reserve, Canadian Rangers, and the civilian workforce. However, it has been a trend in the last two decades, at least, that the Regular force has been prioritized for receiving major end items while soldiers-oriented technologies have been distributed somewhat equally in the regular force and the reserve. For this reason, of all the AI-enabled functions, three would most likely results in the integration of major-end items or, at least, of expensive technologies. Costly AI-enabled systems would mean limited numbers, which consequently requires prioritization most likely at the advantage of the Regular force. However, because it is based on a weak assumption and because it is possible that the decision made would be to field these technologies to the Army Reserve (ARes) at the same time as the Regular Force, depending on the CA strategic orientations at the moment of the fielding, these three functions only lost a half of a point.

Interoperable

This variable is one where the most variability was observed. More precisely, three applications received a perfect score, four received “0.5,” two a neutral score, and one received “-1.” Joint, interagency, and public interactions were considered, but the multinational aspect of the concept had the most influence. This was influenced by the

literature review where multiple authors (Poudrier, Priems, Gizewski, Imbrie et al., to name a few) argued for the importance of interoperability between allies. Imagery analysis, cultural understanding and semi-autonomous air defence received a perfect score because AI-enabled technologies of these functions would be easily interoperable as they would be in the form of software or cloud-based computing systems. For example, a satellite photo has the same characteristics in the United States as in Canada, so it can easily be transferred and exchanged between nations. For the Semi-Autonomous Perimeter Defense, the assumption was made that Canada would acquire US technologies. It is a big assumption, but the United States being the leader of air defence technologies amongst our allies, it is the most likely assumption to make. One of the advantages of buying “off the shelf” or slightly “Canadianized” weapon systems from allies like the US is that it facilitates interoperability. For the 0.5 scores, they received it because there are minor Canadian aspects to them, but they would still be somewhat interoperable with our allies and other government agencies. The neutral scores were given because these applications are network-centric, and networks being different between nations and departments, interoperability is unlikely. The only application that received a negative score is the AI-enabled DRMIS because this resource information management system, in its current form, is uniquely Canadian. Furthermore, each nation's consumption rate, maintenance predictions, and sustainment data are unique, so it would be challenging to render this system interoperable.

Simplicity

This principle was one of the most difficult to assess as the definition given in *Advancing with Purpose* is user-centric: “we will embrace ‘usability or ease of use’

where the perspective and needs of the user are prioritized.”¹⁵⁰ It is not easy to forecast if a technology will be easy to use as the function can be well designed by one manufacturer and not well designed by another. Mainly for this reason, “simplicity” was the criterion where the most “0” or neutral scores were given. However, to advance the research, a few assumptions were made in grading each application. One assumption is that simplicity is often based on the complexity of data input. The more different sets of data you need to input into software, the more complex it is to use correctly. Suppose there are dozens or hundreds of variables that need to be input into a system. In that case, it makes it more complex to use and increases the probability of inputting bad or wrong data, hence lowering the relevance and quality of results. Therefore, a “-1” score was given to the cultural and sentiment understanding application, as a large amount of variables input would most likely be needed to get relevant results in a complex operational environment.¹⁵¹ A grade of “-1” was also given to logistic drones as autonomous unmanned systems are inherently challenging to use in a complex world, as demonstrated in the last five years in the competitive pursuit of autonomous cars.¹⁵² The battlefield being an environment even more chaotic than any North-American road network, it is difficult to imagine autonomous logistics drones as simple to use and implement in horizons 1 and 2. The three AI-enabled functions that received “0.5” or

¹⁵⁰ Department of National Defence, *Advancing with Purpose*, 27.

¹⁵¹ Counter-insurgency operations would be a good example where a large amount of variables input would be needed.

¹⁵² Kareem Othman, “Public Acceptance and Perception of Autonomous Vehicles: A Comprehensive Review,” *AI and Ethics* 1 (2021): 360-359. <https://doi.org/10.1007/s43681-021-00041-8>.

higher scores did so because the interface that would likely be used is similar to what today's soldiers are used to, like software or web-based interface, which maximizes the probability of having more "user-friendly" systems to use.

ADO Ready

This principle is potentially the one that encompasses the most concepts in a unique criterion. However, it was not that difficult to assess as, similarly to the principle of digitization and enhanced networking, the use of AI-enabled technologies, in general, will improve the capability of the Canadian Army to fight better and conduct adaptive-dispersed operations in a close engagement concept. Only two applications did not receive a perfect score: ECM AI-enabled technology to jam, blind, and deceive the enemy, and AI-enabled enemies and adversaries' part of an immersive digital environment for simulation purposes. The former received "0.5," but after a tough deliberation. Someone could argue that offensive electronic warfare (EW) is an essential part of MDO. Still, after further analysis of each time EW and electromagnetic operations were mentioned in *Close Engagement*, it seems that the offensive capabilities of EW are not a priority in comparison with the other applications compared in this chapter.¹⁵³ It is still ADO ready, but not to the same degree. For the DATE simulated enemies for training purposes, however, it is clear that it deserves a negative score for the same reasons it did not receive a positive grade in digitization and enhanced networking. The

¹⁵³ In *Close Engagement*, electronic warfare, or its acronym EW, is mentioned seven times, including in the vignette titled *The Battle of Santa Maria, 2035*. In CE, its purpose is mostly defensive and under the Shield operational function. See Department of National Defence, *Close Engagement*, 23, 31, 39, 50, 54.

only difference is that a DATE simulated enemy would have no direct impact on domestic or expeditionary operations. Actually, they would not be part of the operational digital network at all; they would most likely only be used on civilian-type computers and networks mainly used by civilian contractors as it is used in the Canadian Army at the moment. The only reason it did not receive a “-1” is that it could be used in wargaming as well in the future if modified to fit current adversaries and not only DATE adversaries and counterparts.

Versatility

This was one of the simplest principles to apply as the definition is straightforward. For the CA modernization strategy, being versatile means being useful both in a domestic and expeditionary environment, then across “a diverse set of mission tasks.”¹⁵⁴ As discussed in chapters 1 and 2, versatility is not a strength of current AI and ML technologies (narrow AI). For this reason, several applications cannot transition well from major combat operations to domestic operations. Actually, these technologies (wargame simulator, COA generator, offensive EMS, autonomous perimeter defence, and DATE enemies) would probably have a hard time transitioning from LSCO to counterinsurgency or peacekeeping operations. Because of how the CA doctrine works, these technologies would most likely be focused on major combat operations for good reasons, so they would not be considered versatile. Therefore, they received a score of “-1”. However, some AI-enabled functions would undoubtedly be versatile, like Imagery analysis, protection of digital and radio networks, smart DRMIS, and to a lesser extent,

¹⁵⁴ Department of National Defence, *Advancing with Purpose*, 27.

autonomous logistics drones. Why? Because their use is not dependent on a type or a spectrum of operations. Imagery analysis could be used in all contexts, even for flood and forest fires, and it is the same for sustainment-oriented functions. A smart DRMIS or logistic drone would be as helpful to support major combats in Ukraine as to sustain troops in Quebec during flood relief operations. It is the same for the protection of networks. They would be as relevant in expeditionary operations as in garrison. Because of all these justifications, they received a perfect score, except for logistic drones that received “0.5” because national laws would not necessarily allow for the mass use of air- and ground-based UAS in Canada.

Build Trust

One more criterion needs to be analyzed, the only one that is not a modernization principle: build trust between soldiers and machines. No negative scores were given in this category as no application is assessed to have a negative effect on trust by its employment. Actually, using AI and ML and being conscious of the interaction is a way to build trust between humans and machines. It is assessed that there are three main ways that an interaction with an AI does not build trust. First, the most obvious is when someone uses AI and ML but does not know they are interacting with an AI-enabled machine. Most Canadians and Americans simply do not know that they are constantly in contact with AI and ML on their phones, computers, virtual private assistants, search websites, popular streaming sites, or translation platforms. Without being conscious that you are in contact with artificial intelligence, how can you build trust or distrust toward AI? The second way is when risk or harm is involved. More an activity is risky, less it is likely that someone will trust an AI-enabled technology. For example, a few accidents

involving semi-autonomous cars in the past few years seemed to have substantially impacted the public and lawmakers, which most likely slowed down the mass adoption of these some AI-enabled technologies.¹⁵⁵ Military operations being inherently risky, trust becomes an even more important aspect of AI implementation and use at scale. The third way that AI builds distrust is when the technology is perceived as morally wrong in its purposes.¹⁵⁶ The best examples are the well-known Project Maven, which resulted in the public protest of several Google employees, and lethal autonomous weapon systems (LAWS) that have been the subject of numerous studies and reports in the media.¹⁵⁷ For their perceived purposes, these AI-enabled functions and technologies have most likely built distrust in the population due to their presence in the media.

The only application that falls in one of these categories is the protection of cyber and electromagnetic networks. It received a “0” because it is a technology that would have an impact under the radar of most human users. Most soldiers will simply use it without thinking that an AI-enabled technology protects the networks. Classification and “need to know” would also explain why it would pass under the radar and not contribute to building trust. Someone could argue that signal corps technicians and cyber warriors would be aware, which is true, but it is a marginal number, and it is why it received a neutral score. All the other applications received a score of “0.5” or “1” because it is

¹⁵⁵ Othman, “Public Acceptance and Perception of Autonomous Vehicles,” 358-360.

¹⁵⁶ Priems and Gizewski, “Leveraging Artificial Intelligence for Canada’s Army,” 46.

¹⁵⁷ Cox, “Artificial Intelligence and Multi-Domain Operations,” 86.

assessed that they will positively impact the trust of soldiers toward machines. The difference is one of degree. It is evaluated that imagery analysis, cultural understanding, smart DRMIS, and logistic drones would have a high degree of positive impact on soldier's trust because the risk involved in using the technology would be minimal. In other words, the output or results produced would have a minimal negative impact in the case of "failure modes" and a low probability of dramatic consequences. On the other hand, the functions that received "0.5" could have more dramatic impacts in case of mistakes, bad advice, or failures. The only exception is the DATE enemy AI, which received "0.5" because soldiers are used to playing or experimenting with this kind of "gaming" technology, so it would have a minimal impact on building trust in AI-enabled systems.

Results Analysis and Recommendations

The results have emerged and been described, so it is now time to offer an analysis and final recommendations. To begin with, here is the overall ranking, followed by separated rankings for horizons 1 and 2:

Table 8. Ranking of AI-Enabled Applications to Pursue for Horizons 1 & 2

Ranking	AI Applications	Score
1	Imagery analysis	7
2	Smart DRMIS	4.5
3	Wargame simulator	4
3	Protection of Networks	4
3	Cultural understanding	4
4	F & ECOA Generator	3.5
4	Semi-Auton. Perimeter AD	3.5
5	Logistics drone	3
6	Jam, blind, deceive EMS	2.5
7	DATE Simulation	1.5

Source: Created by author.

Table 9. Rankings of AI-Enabled Applications Separated by Horizon

Ranking of AI-Enabled Applications to Pursue for Horizon 1			Ranking of AI-Enabled Applications to Pursue for Horizon 2		
Ranking	AI Application	Score	Ranking	AI Application	Score
1	Imagery Analysis	7	1	Cultural Underst.	4
2	Smart DRMIS	4.5	2	F&EOA Generator	3.5
3	Wargame simulator	4	2	Semi-Auton. Perimeter AD	3.5
3	Protection of Networks	4	3	Logistics drone	3
5	Semi-Auton. Perimeter AD	3.5	4	Jam, blind, dec. EMS	2.5
6	Date Simulation	1.5			

Source: Created by author.

By themselves, these rankings can answer the primary research question: using a ranking system to predict the ability to impact the Canadian Army operations, what functions of Artificial Intelligence should the Canadian Army pursue with 5 and 15-year timeframes (horizons 1 and 2)? However, by analyzing them more thoroughly, a few highlights emerged. First, there are clear first and last positions in the overall ranking. With a margin of 2.5, which is the most considerable margin of the results, AI-enabled

Imagery analysis is the first function of AI that the Canadian Army should pursue. On the opposite, AI-enabled enemies and adversaries for simulation purposes finished last by a margin of 1 from the second last position. To note, there is only a difference of 2 points between the second and 6th position (or second-last), which tells a lot about the potential of all AI-enabled applications selected.

For horizons ranking, it is essential to note that only one application is in both: semi-autonomous perimeter air defence. The reason why, as explained earlier, is because the technology already exists and is used or is on the verge of being used by some countries, including the United States, yet it is unlikely that Canada would acquire this technology fast enough to implement it in CA formations within five years. Because of this fact, and because AI-enabled AD technologies have the potential to evolve dramatically as part of ADO and MDO within the next 15 years, it is the only function that makes both rankings. To be highlighted, 66% of horizon 1 applications received a better score than 80% of horizon 2's. This can potentially be explained by the fact that these technologies are more software-based versus hardware-based, for the most part, therefore they seem less complex and easier to imagine. The criterion of "build trust" could have also played a role. It is much more complicated to forecast the basic trust level of soldiers for AI-enabled machines in the future.

Talking about this criterion, a critic of these results could argue that it should not have been part of the comparison as it is not a modernization principle. It could be a fair argument, so rankings have been produced without this specific criterion.

Here are the results:

Table 11. Ranking of AI-Enabled Applications to Pursue in Horizons 1 & 2 - without “Build Trust”

Ranking	AI Application	Score
1	Imagery analysis	6
2	Protection of Networks	4
3	Smart DRMIS	3.5
3	Wargame simulator	3.5
3	Cultural understanding	3
4	F & ECOA Generator	3
4	Semi-Auton. Perimeter AD	3
5	Logistics drone	2
6	Jam, blind, deceive EMS	2
7	DATE Simulation	1

Source: Created by author.

Table 12. Rankings of AI-Enabled Applications Separated by Horizon – without “Build Trust”

Ranking of AI-Enabled Applications to Pursue for Horizon 1 - Without "Build Trust"			Ranking of AI-Enabled Applications to Pursue for Horizon 2 - Without "Build Trust"		
Ranking	AI Application	Score	Ranking	AI Application	Score
1	Imagery Analysis	6	1	Cultural Underst.	3
2	Protection of Networks	4	2	F&ECOA Generator	3
3	Smart DRMIS	3.5	2	Semi-Auton. Perimeter AD	3
3	Wargame simulator	3.5	3	Logistics drone	2
5	Semi-Auton. Perimeter AD	3	4	Jam, blind, dec. EMS	2
6	Date Simulation	1			

Source: Created by author.

The only difference observable in the rankings is that protection of networks (cyber and EMS) jumps to the second position in the overall and horizon 1 rankings. This is quite interesting as it had received a low score for “build trust” because most users of an AI-enabled technology of this nature would not even know they would engage with AI

and ML. Therefore, it highlights how it scored well with several other modernization principles.

Another important aspect of this ranking is that multiple technologies received identical scores and ranking positions. For the final ranking and overall recommendations, a purely qualitative choice was made to order them based on the different findings offered by all chapters of this research:

Table 13. Final Ranking of AI-Enabled Applications to Pursue for Horizons 1 & 2

Ranking	AI Applications	Score
1	Imagery analysis platform, including fight against disinformation	7
2	Control of overall logistics capability (smart DRMIS)	4.5
3	Protection of Networks (Cyber & EMS).	4
4	High-Frequency Wargame Simulator	4
5	Cultural and sentiment understanding	4
6	Friendly and Enemy course of action (COA) generator	3.5
7	Semi-Autonomous Perimeter Air-Defense (GBAD)	3.5
8	Drones/robots for delivery and return of logistics	3
9	EMS AI-enabled technology to jam, blind, and deceive the enemy	2.5
10	DATE AI-enabled enemies and adversaries for simulation purposes	1.5

Source: Created by author.

To build this final ranking, three choices had to be made. First, which applications that have received a “4” have the best ability to impact the Canadian Army operations in the next 15 years? The answer is the protection of Cyber and EMS networks because, as explained in the last paragraph, it finished second when the “build trust” criterion was taken out. Second, a decision had to be made between “high-frequency wargame simulator” and “cultural and sentiment understanding.” Ultimately, the former was chosen to occupy fourth place because it is assessed that a wargame simulator has the

most probability of influencing the main effort, which is “training, equipping, and preparation” for combat operations or LSCO.¹⁵⁸ However, it does not undermine the fact that AI-enabled cultural and sentiment understanding technologies should be pursued as well. Third, the last decision that had to be made was which application between FCOA/ECOA generator and semi-autonomous perimeter air-defence would occupy the sixth place. It was decided that the COA generator would be in front of air defence simply because the United States is already the leader in research and use of semi-autonomous perimeter air defence. Therefore, it would be particularly challenging for Canada to lead and influence the development of this technology, as explained at the beginning of this chapter.¹⁵⁹

Table 14. Final Ranking - AI Applications the CA Should Pursue in Order of Priorities

Priorities	AI Applications
1	Imagery analysis platform, including fight against disinformation
2	Control of overall logistics capability (smart DRMIS)
3	Protection of Networks (Cyber & EMS).
4	High-Frequency Wargame Simulator
5	Cultural and sentiment understanding
6	Friendly and Enemy course of action (COA) generator
7	Semi-Autonomous Perimeter Air-Defense (GBAD)
8	Drones/robots for delivery and return of logistics
9	EMS AI-enabled technology to jam, blind, and deceive the enemy

Source: Created by author.

¹⁵⁸ Department of National Defence, *Advancing with Purpose*, 55.

¹⁵⁹ See “Key Considerations and Limitations.”

Before transitioning to the conclusion, the last step is answering the primary research question. Using a ranking system to predict the ability to impact the Canadian Army operations, what functions of Artificial Intelligence should the Canadian Army pursue with 5 and 15-year timeframes (horizons 1 and 2)? The Canadian Army should pursue all AI-enabled functions compared in this research, except DATE AI-enabled enemies and adversaries for simulation purposes. According to the priorities established in the table below, these nine applications should receive proportional human, material, and financial resources. Still, special attention should be given to priorities 1 to 4 as they are required to prevail against our adversaries within five years. However, all the below AI-enabled priorities should be pursued as soon as possible if the Canadian Army, the Canadian Armed Forces, and Defence Research and Development Canada are not already doing so. At the moment of this writing, our allies and adversaries are working hard at getting the advantage in AI-enabled technologies. The Canadian Army cannot lag if it wants to stay in an advantageous position on the global stage.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

From the beginning, this thesis aimed at making sense of the vast number of articles, reports, and opinions written about the military applications of artificial intelligence and machine learning in land warfare. More precisely, it had the objective of giving a Canadian Army perspective on this crucial topic, which seems to be lacking even if many scholars and practitioners agree that AI will change how wars are conducted.¹⁶⁰ A large number of far-reaching narratives have been written on the subject as the concepts of narrow and general AI are often interchangeably used to discuss AI-enabled applications, which make great science-fiction movies and novels, but lack realism and practicability, particularly at the operational and tactical levels. The hope is that this study is not adding to the impracticable array of literature on the subject. Instead, it is developing well-informed, practical recommendations for Canadian Army decision-makers and staff working on modernization or simply for any Defence team member working at making the CA better.

¹⁶⁰ Priems and Gizewski, Noël, Poudrier, Kissinger et al., Army Futures Command, and Cox are among the authors cited in this research that would most likely agree with this statement. See chapters 1 and 2 for more details on how each author thinks AI and ML could change warfare.

Scope and Purpose

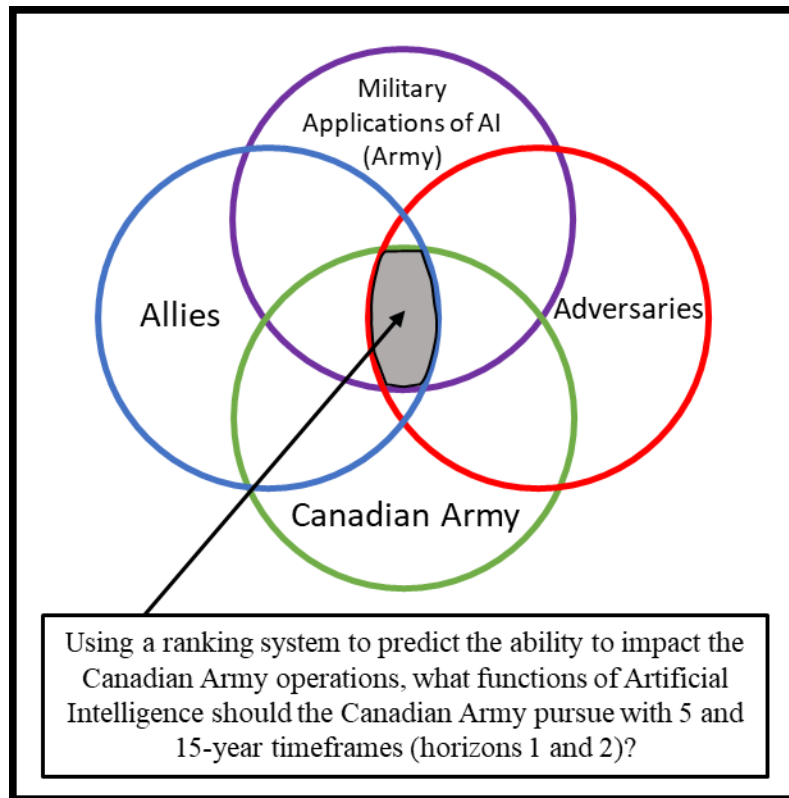


Figure 12. Thesis' Summary

Source: Created by author.

The diagram in figure 11 summarizes how the secondary research questions helped answer the primary research question. From the examinations of each secondary research question (military applications of AI in land warfare; Canadian Army needs, limitations, and considerations; US Army current plan and way ahead; China and Russia's focus in pursuit of AI) arose the selection of ten AI-enabled applications. They were compared using criteria based on the CA modernization principles and the concept of "build trust between soldiers and machines." This comparison ultimately led to a

ranking that informed the final recommendations of this research and answered the primary research question.

Of necessity, the research was limited in scope. Among Canada's long list of allies, only the United States was studied in detail, primarily because of lack of time and the difficulties in finding relevant resources for other allied land forces in a timely manner. Similarly, only China and Russia were looked upon for adversaries. Yet, the most significant limitation was the selection of "only" ten AI-enabled applications. So many other functions or applications could have been compared, which could have arguably changed the final recommendations. Still, ten was assessed as an excellent sampling for answering the primary research question while covering all operational functions. Furthermore, the study was focused on land warfare at the tactical and operational levels. A lot more could have been studied and compared in other domains, dimensions, or from a joint point of view. The last major delimitation was that ethical considerations were mainly left undiscussed. Yes, the Canadian Army-specific considerations and constraints highlighted by Priems and Gizewski included some aspects of ethics,¹⁶¹ but not enough to consider that ethical considerations had a leading role in this thesis.

Summary Recommendations

In the end, the main recommendations can be summarized in a table and four points:

¹⁶¹ Priems and Gizewski, "Leveraging Artificial Intelligence for Canada's Army," 46-49.

Table 15. Final Ranking - AI Applications the CA Should Pursue in Order of Priority

Priorities	AI Applications
1	Imagery analysis platform, including fight against disinformation
2	Control of overall logistics capability (smart DRMIS)
3	Protection of Networks (Cyber & EMS).
4	High-Frequency Wargame Simulator
5	Cultural and sentiment understanding
6	Friendly and Enemy course of action (COA) generator
7	Semi-Autonomous Perimeter Air-Defense (GBAD)
8	Drones/robots for delivery and return of logistics
9	EMS AI-enabled technology to jam, blind, and deceive the enemy

Source: Created by author.

1. The Canadian Army should pursue all AI-enabled functions in the table above as soon as possible if it is not already doing so. According to their ranking, they should receive proportional human, material, and financial resources.

2. Special attention should be given to priorities 1 to 4 as they are required to help the CA prevail against our adversaries within the next five years.

3. AI-enabled Imagery analysis in general, and AI-enabled imagery analysis fighting disinformation in particular, should receive particular attention, as they were the most promising technology discussed in this research by a good margin.

4. These priorities should be described and explained in a Canadian Army AI Strategy, so they can be contextualized and put into perspective (see below for more details).

Unexpected Recommendations

In addition to the above recommendations, the research stumbled upon a few unexpected on broader AI-related topics:

1. The Canadian Army needs an AI Strategy. The first reason why is the Army needs to reflect and make decisions on how it wants AI and ML to help meet the ambitions of *Close Engagement*. AI is too vast, and resources are too scarce to let it play out without being deliberate. Second, military professionals, researchers, scholars, and scientists need a vision and intent to actively participate in developing and implementing this technology. Academia and the private sector being at the forefront of AI development worldwide, they cannot get involved and join military research efforts without a strategy or at least a vision on the use of AI in the Canadian Armed Forces and the Canadian Army. The US *2020 Army Artificial Intelligence Strategy*¹⁶² is a good document if CA policymakers require inspiration.

2. Trust between soldiers and machines is key to the operationalization of AI in the Canadian Army and any military force. The concepts of explainability, “fail modes,” humans “in” and “on-the-loop,” and electronic literacy, all linked to trust, must be considered when new technologies are designed. Building a long-lasting trust between soldiers and machines will take time and a deliberate approach, knowing that one big mistake or incident could dramatically impact levels of trust in AI-enabled technologies overnight. A possible solution to enhance trust is by implementing AI and ML gradually into units and formations by starting within permissive and low-risk functions of AI. For example, it is less risky to use AI-enabled technologies in sustainment than for the “act” operational function where the lives of people could be in play. In the same vein, it would be wise to gradually start with autonomous “recommending” AIs before moving to

¹⁶² HQDA, *2020 Army Artificial Intelligence Strategy*.

“acting” AIs that would make important decisions on their own. Bottom line is, building trust needs to be deliberate and gradual if the Canadian Army, or any military forces for that matter, wants to be successful in operationalizing AI and ML at the operational and tactical levels. It is one more reason why the CA needs to develop an AI Strategy.

3. As the Canadian Army does not have the resources, capabilities, or expertise to research specific aspects of land warfare, it is assumed that it will rely on its Allies, most likely the US, to research and develop certain technologies or capabilities. AI and ML are no exceptions to this rule. To counterbalance this fact, the Canadian Army could find a specialty or a niche in one or a few military functions of AI relevant to multi-domain operations. By doing this, Canada would advantageously develop specific and unique expertise and get recognition from its allies and partners. Multiple niches could be pursued, but among the functions studied in this research, planning and decision-making aids like the wargaming simulator and COA generators could be good options to explore. The same would potentially be valid with cultural and sentiment understanding technologies. Both would take advantage of the Canadian Army’s strengths and expertise, therefore maximizing the chance to succeed.

4. A data collection and sharing policy is needed in the CAF, CA, and DND. Data is one key to ML and AI with computing power, algorithms, and code frameworks. Even if DND is not officially the lead department on this topic, it must think of how it wants to handle this sensitive aspect of modernization. Do we want to collect on our soldiers? Would we be ready to share our data with our closest allies? Do we want to rely only on commercial data? Do we want to conclude multilateral agreements for data-sharing or only bilateral ones? These are all questions that a data collection and sharing strategy

would have to answer. This is all the more important because we will have to rely on our allies for most of AI modernization in the future, so sharing data among partners could be paramount for keeping an edge over our adversaries. Being deliberate in collecting and managing data is in the CAF's main interest and the ones of its soldiers, airmen, sailors, and special operators.

Recommendations for Subsequent Research

The following four avenues for future research come from the limitations and delimitations placed on the research. First, a similar study would be required at a higher classification level and in partnership with subject matter experts to ensure the recommendations brought forward in this thesis are accurate and still relevant. The same methodology could be used, but the assumptions and recommendations could be confirmed or denied by focusing the literature review on classified sources and reports. Similarly, this research could be expanded by consulting with subject matter experts in AI, ML, and modernization to verify if the findings are accurate through their specialist's lens. Using human subjects' methodology, formal interviews and surveys could be done with these experts, using this thesis as the foundation for conducting these engagements.

Second, other allies than the United States should be looked at to understand what other nations are anticipating and currently working on. My recommendations would be the following countries: Australia, the United Kingdom, France, and Israel. The two formers because they are part of the five eyes community, and the two latter because they have strong defence industry sectors, including in research and development, and contemplate military art and sciences differently than the western English-speaking countries. Doing this research would also help understand what other armies, more

similar to Canada in combat power and resources, are currently pursuing and forecasting. Australia would arguably be the first to research as they have a similar “medium-power” status and their armed forces are particularly dynamic at the moment, being part of the Indo-Pacific region, the current United States’ main effort.

Third, as the importance of trust is one of the unexpected recommendations, further research on this subject would be needed. Research on this topic could give recommendations on designing AI-enabled technologies to enhance trust in the mid and long term. Furthermore, at the institutional level, it would inform the development of a CA AI Strategy that would take this fundamental aspect into account by including trust-enabling milestones and lines of effort. Cox’s *Military Review* article and the sources he provides in addressing this specific issue would be an excellent starting point for research on this topic.

Fourth, it could be argued that the present research is potentially too broad in its analysis and ultimately in its conclusions. A solution to this lack of focus could be subsequent research focused on specific operational or warfighting functions, using a similar method. It would lead to more in-depth analysis and more actionable conclusions and recommendations. A study of this type would also allow more time to review literature to assess the technical feasibility of the most promising technologies.

Closing Thought

AI and ML will change warfare, yet the question is how and when. The world is currently in a race for AI in all aspects of society and instruments of national power, including the military. If an “arms race” is “a pattern of competitive acquisition of

military capability between two or more countries,”¹⁶³ there is no doubt it is currently happening with AI and ML, at least between the United States and China, but more likely with most of the current medium and great powers. The question is, where does Canada, the Department of National Defence, the Canadian Armed Forces, and the Canadian Army fit in this race. So far, it seems that it does not want to take an active role as nothing significant has been written on the matter. It is a valid course of action if DND wants to observe in what direction its allies and adversaries are going before making significant decisions. However, it cannot wait much longer. If Canada wants to keep its leading position in AI and not just constantly react to its allies’ and adversaries’ every move, it is now time to be deliberate about the development, implementation, and use of military AI-enabled technologies. Reflecting on and writing a Canadian Army AI Strategy, then developing, resourcing, and acquiring the nine AI-enabled applications analyzed in this research would be a good step in this direction. It would be a great way to contribute to our critical alliances and be a leader in potentially the next (or current) revolution in military affairs.

¹⁶³ Sam Perlo-Freeman, “Arms Race,” Encyclopedia Britannica, last modified January 27, 2020, <https://www.britannica.com/topic/arms-race>.

APPENDIX A

DEFINITION OF THE CANADIAN ARMY MODERNIZATION PRINCIPLES¹⁶⁴

Digitization and enhanced networking. Future networks must be designed and implemented to enhance shared understanding, the speed of decision-making, and the effectiveness of command and control. This has the cumulative potential for transformational change. Failure to exploit these networks or, conversely, become entirely dependent on them, has potential risks that may negate an advantage or even leave the Canadian Army at a significant disadvantage. Further, emerging advances in artificial intelligence, such as its use within predictive planning tools, has the potential to greatly shorten the decision-action cycle. The Canadian Army's embrace of digital excellence is foundational to modernization. Society is on the edge of burgeoning artificial intelligence and other digitally-driven technologies. As an increasing proportion of soldiers and defence civilians are digitally-inclined, the Canadian Army must harness data and embrace digital culture to benefit from their potential and act as a shield from the negative aspects of new technologies. Particularly, leaders must stay attuned to soldier skill sets to ensure operators possess the requisite capabilities. In many cases, this will require consistent retraining on current and new systems.

One Army. Only One Army will be able to manage the array of concurrent operational demands. The Regular Force, ARes, CR, and the civilian work-force will be a single operating entity. The full integration of the Regular and Reserve components, and

¹⁶⁴ Department of National Defence, *Advancing with Purpose*, 26-27.

capability in particular, will be achieved where the optimum capacity of each component will enable meeting the readiness and operational output demands of the future.

Interoperable. Interoperability with multiple organizations is vital for the way Canada prepares, trains, and fights. It is required across the full spectrum of joint, interagency, multinational, and public interactions. In the pan-domain fight, joint interoperability is indispensable. The Canadian Army will also achieve interoperability with key ABCANZ and NATO allies. Further, the Canadian Army will be able to work alongside UN or coalition partners when required.

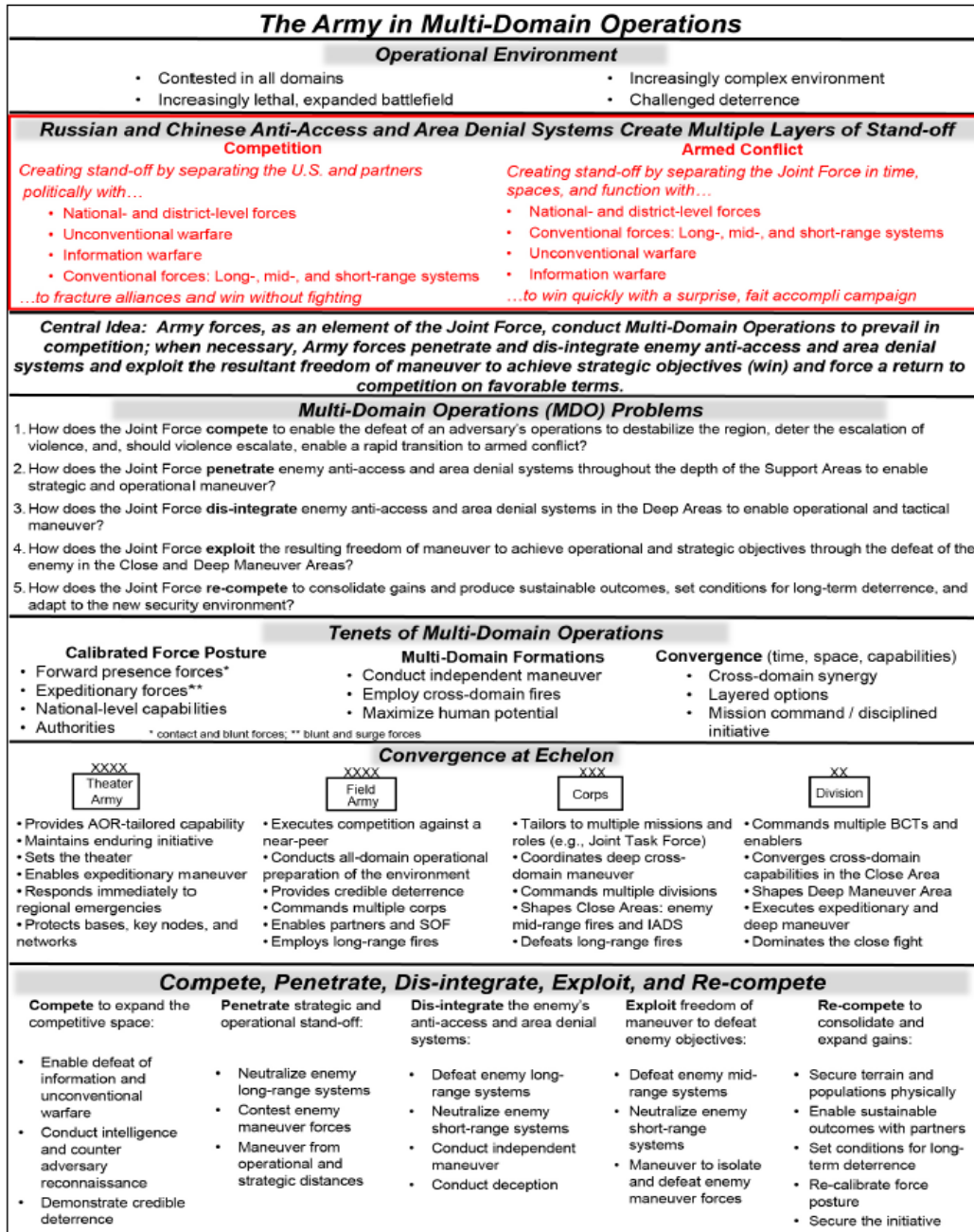
Simplicity. Technology must absolutely be leveraged to assure military superiority, but the Canadian Army's approach, systems applications, and methodology must preserve simplicity. In all, we will embrace "usability or ease of use" where the perspective and needs of the user are prioritized. Simplicity is the key to effective maintenance and equipment use.

Adaptive Dispersed Operations (ADO) Ready. As detailed in Close Engagement, the Canadian Army will prepare for ADO as a baseline and way of operating. The principles and deductions contained in Close Engagement are to be understood and incorporated by all Canadian Army members.

Versatility. The Canadian Army will seek to develop and acquire capabilities that achieve the widest utility across both domestic and expeditionary environments, thus achieving the most efficient use of funds. This approach will also guarantee equipment familiarity across a diverse set of mission tasks.

APPENDIX B

THE ARMY IN MULTI-DOMAIN OPERATIONS – LOGIC MAP



Source: U.S. Army Training and Doctrine Command (TRADOC), TRADOC Pamphlet 525-3-1, *The U.S. Army in Multi-Domain Operations 2028* (Fort Eustis, VA: TRADOC, December 2018), v.

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