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DECISION ADVANTAGE: THE IMPACT OF MACHINE LEARNING ON CAF STRATEGIC PLANNING

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Solo Flight

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Recognized as strategic documents that will embrace future technology, both the Canada Defence Plan[1] and Canada's Defence Policy – Strong, Secure Engaged[2] (SSE), fail to mention a critical aspect of future technology: Machine Learning (ML). Further, ML is only mentioned once in the 2019 Department of National Defence (DND) and Canadian Armed Forces (CAF) digital vanguard document: the DND and CAF Data Strategy.[3] This is particularly concerning given that the ML concept is conspicuously absent when discussing the modernization of the business of defence and technological developments within the context of defence strategic planning. While the aforementioned strategies neglect ML, there are promising initiatives underway within the DND - most notably through the creation of an Assistant Deputy Minister (Data, Innovation and Analytics) (ADM (DIA)) Directorate which is charged to provide the CAF leadership with "expertise …to make data-driven and evidence-based decisions by providing data integration and analytics support."[4]

The ability for the CAF senior leaders to leverage ML through the provision of unbiased and either structured or unstructured data will be led by ADM(DIA). While doing so, the CAF will need to consider a level of interoperability with both strategic planners and partner military and OGDs that have already embraced ML in order to make

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[1] Canada. Department of National Defence. *Canada's Defence Plan*. Ottawa: Department of National Defence, May 18, 2018.
[2] Canada. Department of National Defence. *Strong, Secure, Engaged: Canada's Defence Policy*. Ottawa: Department of National Defence, 2017.
[3] Canada. Department of National Defence. *The Department of National Defence and Canadian Armed Forces Data Strategy*. Government of Canada, December 3, 2019.
[4] Canada. Department of National Defence. *Assistant Deputy Minister (Data, Innovation and Analytics).* Government of Canada, August 2, 2019

the "technology a centerpiece of … warfighting."[5] Presently, the CAF lacks substantive ML policy at the strategic level. This paper will argue that by increasing its investment in ML policy, the CAF will maximize and strengthen its strategic planning capability. This will ensure the CAF is situated to "Anticipate, Adapt and Act'[6] as mandated by SSE. To understand how ML can be leveraged by the CAF in a strategic context, this paper will begin by discussing the fundamentals of ML in a military context, highlight activities by near-peer militaries in the ML space, discuss CAF data integration framework, and finally suggest ML policy components compatible with strategic planning tools - most notably Capability Based Planning (CBP).

Machine Learning

ML is not a new concept and falls under the computer science umbrella of Artificial Intelligence (AI). The phrase "Machine Learning" was first introduced in 1959[7] and is described as "as a field of study that gives computers the ability to learn without being explicitly programmed."[8] One the first applications of ML was to discriminate between shapes such as triangles and squares. Over the years, the ML description has evolved to include "the automated detection of meaningful patterns in data."[9] Doctrinally, the CAF defines ML as a subset of AI that uses "programs that can teach themselves to learn and act."[10] To realize the benefits of artificial intelligence, large datasets that are

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[5] Groll, Elias. *The Pentagon's AI Chief Prepares for Battle*. Wired, December 18, 2019.
[6] Canada. Department of National Defence. *Strong, Secure, Engaged: Canada's Defence Policy.* Ottawa: Department of National Defence, 2017.
[7] Wlodarczak, Peter. 2019. Machine Learning and Its Applications. Vol. First edition. Boca Raton: CRC Press.
[8] Ibid., 4.
[9] Aaron F. Brantly. *When Everything Becomes Intelligence: Machine Learning and The Connected World*. Intelligence and National Security, 2018, 568.
[10] Canada. Department of National Defence." *The Department of National Defence and Canadian Armed Forces Data Strategy*. Government of Canada, December 3, 2019

largely removed of bias are required; the data can be structured or unstructured, depending on the particular need."[11]

It is important to distinguish between the characteristics of ML and the concept of Data Mining (DM). DM is defined as "the process of discovering patterns in data."[12] While this sounds similar to ML, the distinction lies in the aim. Where DM is focused on patterns and trends, ML "aims to make predictions by building models that can foresee some future outcome."[13] As such, given the predictive properties of ML, there are many contemporary uses for ML policy that can be leveraged by CAF strategic planning framework that this paper will highlight further below. To better orientate how the CAF can leverage ML capabilities through policy, the following are notable (but not exhaustive) ML aspects and techniques applicable to strategic planning: supervised learning, evaluation of learner, and semi-supervised learning. These techniques will be further explained in their application to CAF strategic planning throughout the paper.

Despite its many advantages, it must be recognized that ML is neither one size fits all nor is it a panacea for all organizational planning challenges. Rather, utilization of ML bears consideration when certain conditions exist. Conditions include data complexity problems such as a multitude of rules that require to be applied to data or if there are scalability issues where the quantity of data outmatches the capacity to process it.[14] This can be a resource intensive undertaking as best practices recognize that data scientists are used for labeling and inputs. Further, the quality of data is vital to algorithm efficacy -

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[11] Ibid., 32.
[12] Wlodarczak, Peter. 2019. Machine Learning and Its Applications. Vol. First edition. Boca Raton: CRC Press, 5.
[13] Ibid.
[14] Ibid., 164.

especially data that can be correlated with "ground truth."[15] This is why in some cases military organizations are ideal users of ML because data collected in the field or the environment through human and machine collection can provide valuable data insights vice purely theoretical. To understand where ML could best be situated within the CAF strategic planning space, this paper will briefly discuss contemporary applications of ML either being used or planned to be used by near peer militaries and coalitions such as the North Atlantic Treaty Organization (NATO).

Modern Defence Applications of Machine Learning

ML is presently used by partner nation militaries in areas such as health care, logistics, and security categories, while planning efforts are under way for its use by multi-lateral organizations such as the North Atlantic Treaty Organization (NATO). In the United Kingdom, ML is used to study personnel who have probable Post Traumatic Stress Disorder (PTSD). Supervised ML methods were used to reliably identify PTSD in certain military populations based on self-reported data. This study was conducted with a view to "reduce the burden on public health and improve operational efficiencies by enabling early intervention before chronic manifestation of symptoms."[16] It should be noted there were limitations in the study which included bias as well as the fact that the data collected was not intended to be used in a ML model.

In the United States, ML is being used for predictive maintenance. Following the Air Forces and Marines' use of ML for logistics planning, the US Army recently hired a firm to assist with maintenance and spare parts. The aim is to optimize the supply chain

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[15] Ibid.

[16] Daniel Leightley, Victoria Williamson, John Darby & Nicola T. Fear (2019) *Identifying Probable Post-Traumatic Stress Disorder: Applying Supervised Machine Learning To Data From A UK Military Cohort*, Journal of Mental Health, 39.

and understand "how to buy spare parts when they're needed instead of keeping large stockpiles on supply room shelves."[17] One of the main challenges in this undertaking is the standardization of data as some of it is being extracted from 20 year old aircraft maintenance logs. This tactical use of ML across the organization feeds strategic planning outcomes such as capital investment.

Meanwhile, NATO is examining the use of ML in areas such as threat evaluation, underwater mine warfare, cyber security, intelligence analysis, and command and control.[18] One practical example of ML application in threat evaluation is ship detection modeling. A ML method can be "used to generate normality models from vessel movement data. Any vessel movement that deviates from the normality models is considered anomalous and presented to operators for manual inspection."[19] Considering that the use of ML by any one nation or entity presents challenges for a multi-lateral organization as big as NATO to adopt ML, there are challenges ahead. These include streamlining military organizations to adapt their data collection processes to a common standard, inadequate transparency and interpretability of ML models, and vulnerability to adversarial attacks such as deception through manipulation of an input signal or data.[20] Consequently, as the CAF develops its own ML policy to use with strategic planning, a factor when considering its strategic effectiveness will also depend on its level of interoperability and compliance with allied nations and multi-lateral coalition's ML policy framework, especially in view of how data in managed and ingested.

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[17] Weisgerber, Marcus. *US Army Hires AI Firm to Predict When Aircraft, Vehicles & Weapons Will Break*. Defense One, November 21, 2019.
[18] Svenmarck, P., Luotsinen, L., Nilsson, M., Schubert, J. (2018). *Possibilities and challenges for artificial intelligence in military applications*. Neuilly-sur-Seine: NATO Research and Technology Organization, paper S1-5
[19] Ibid., 4.
[20] Ibid., 2.

CAF Data Integration Framework

Canada's Defence Policy highlights many areas that will depend on quality data and acknowledges that much of Canada's advantage relies upon "agile information management and technology tools to aggregate and manipulate large quantities of data."[21] Consequently, the DND and CAF have promulgated a data strategy. Drivers of the CAF Data Strategy include the changing nature of conflict … volume of data, data driven technologies, and the requirement to measure and report on outcomes.[22] A principal aim of the CAF Data Strategy is to "provide direction and guidance to DND/CAF as it adopts data driven-approaches to decision-making and delivering the business of defence."[23] Stewardship of this strategy falls within ADM (DIA) to deliver data management, policy, tools, and environment – and will be done with a measure of congruence Government of Canada initiatives in the AI space.[24] Without a robust data management policy and strategy within a strategic planning context, it will be difficult to enable the use of ML in a strategic planning context.

ADM (DIA). This is a young organization that stood up in July 2018 within DND in recognition that the future of defence in Canada "will place a greater emphasis on information technologies, data analytics, deep learning, [and] autonomous systems."[25] Its mission is to provide CAF and DND leaders with the "expertise required to make data

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[21] Canada. Department of National Defence. *Strong, Secure, Engaged: Canada's Defence Policy.* Ottawa: Department of National Defence, 2017.
[22] Canada. Department of National Defence. *The Department of National Defence and Canadian Armed Forces Data Strategy*. Government of Canada, December 3, 2019
[23] Ibid., 2.
[24] CIFAR. Pan-Canadian Artificial Intelligence Strategy Accessed May 4, 2020.
[25] Canada. Department of National Defence. *The Department of National Defence and Canadian Armed Forces Data Strategy*. Government of Canada, December 3, 2019

driven and evidence based decisions by providing data integration and analytics support."[26] It is comprised of two components: Director General (DG) (Analytics Support Centre) (DGASC) and the DG (Data, Strategy and Innovation) (DGDSI). The DGASC enables the "adoption and progression of enterprise analytics capacity across the enterprise. It is comprised of the following five sections: Solution Enablement, Data Integration and Enablement, Training, Technical and Advanced Analytics."[27] DGDSI supports the "digital transformation across the Defence Team. It establishes and implements data governance framework and policies, and maintains data management and enterprise-wide value cases. It leverages innovation and change management for digital transformation."[28]

Despite its institutional youth, the CAF Data Strategy coupled with the creation of ADM(DIA) creates an ability and opportunity to develop ML policy that will provide a value proposition in terms of strategic planning. These opportunities will be discussed in detail later in this paper. Further, ADM(DIA) has been given authorities within the CAF Data Strategy to affect significant changes that will guide the CAF into a data centric future. The roadmap includes four key activities: Implement data governance; Implement data quality approach; Implement data policies; and Define data literacy.[29] Strategic vison in this space will all create an opportunity to increase investment in ML policy, which in turn will strengthen the CAF's strategic planning capability. To maximize ML in the

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[26] Canada. Department of National Defence. *Assistant Deputy Minister (Data, Innovation and Analytics).* Government of Canada, August 2, 2019.
[27] Ibid.
[28] Ibid.
[29] Canada. Department of National Defence. *The Department of National Defence and Canadian Armed Forces Data Strategy*. Government of Canada, December 3, 2019

strategic planning space, there are a few considerations when creating policy within CAF strategic planning framework.

CAF Strategic Planning Framework

To understand where ML fits within the CAF strategic planning tool box, this paper will quickly review which instruments inform Canada's Defence Plan. The CAF uses several different foundational planning tools which include CBP, the Investment Plan, the Defence Team Human Resource Strategy, the Canadian National Military Strategy, the Force Posture and Readiness Directive, the Integrated Risk Management Policy and Guidelines and the Departmental Results Framework to inform strategic management decisions.[30] Notwithstanding the quality and recording of historical data, ML can be applied to all of the aforementioned planning tools. For the purposes of predictive planning efficacy that will enable to CAF to "Anticipate, Adapt, and Act"[31], ML policy has significant congruence with CBP.

Capability Based Planning. This is a type of strategic military planning under the stewardship of the Chief of Force Development (FD). CBP "provides a broad overview of the entire strategic CAF capability portfolio, defines future requirements based on future trends and assesses what capability areas require Investment, Divestment and Sustainment (IDS) decisions."[32] Doctrinally, it is a process vice end state that results in outputs such as the Investment Plan (IP) which is aligned with Force Capability Guidance (FCG) , which is strategic direction set out by the CDS and finally, the Multi-Year

[30] Canada. Department of National Defence. *Canada's Defence Plan*. Ottawa: Department of National Defence, May 18, 2018.
[31] Canada. Department of National Defence. *Strong, Secure, Engaged: Canada's Defence Policy.* Ottawa: Department of National Defence, 2017
[32] Ibid., 5.

Establishment Plan (MYEP) which expresses "strategic force structure direction, aligned to the FCG's capabilities."[33]

From a horizon scanning perspective, CBP uses three different timelines, called "horizons". Horizon One is zero to five years, Horizon Two is 5 to 10 years, and Horizon Three is 10 to 30 years. While CFD is responsible for all three horizons, CBP mostly concerns itself with the process of "analysis of [Future Force] effectiveness 15 years into the future."[34] It achieves this through a three phase process: initiation, assessment, and integration. While ML can be leveraged throughout the three phases, it would be most useful during Phase 1 which ingests data inputs to create a Future Security Environment (FSE) model and Force Development Scenario Set (FDSS), while ensuring congruence with Canada's Defence Policy (CDP). Application of ML Policy regarding FSE development and the FDSS inputs has the potential to create a decision advantage for senior leaders as they plan Future Force capabilities and resourcing.

Future Security Environment. The FSE is predicated on past and current trends. This is a concept that "informs the required strategic outcomes in context of the most likely environments and battlespace in which these outcomes will occur…FSE establishes the external factors and competing effects that the CAF will likely face in operations."[35] FSE also enables the development of ground up FD scenarios. To build these scenarios, mission force and associated capabilities data inputs are required. "Collected capability and Force Element (FElm) data is studied to "determine patterns and trends within the larger system. Here gaps, surpluses and capability-to-value assessments can be made. Out

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[33] Canada. Department of National Defence. Capability-Based Planning Handbook. Ottawa: Chief of Force Development, 2014, 57.
[34] Ibid., 67.
[35] Ibid., 7.

of these patterns, possible changes to the existing CAF capabilities may be made."[36]

FElm inputs include business areas such as personnel, material, maintenance, and infrastructure.[37]This is data that can be leveraged by ML to assist with providing a decision advantage. Instead of manually analyzing the data of each of these scenarios to identify patterns – which is a time consuming and resource intensive, the CAF can leverage the Supervised Learning technique of ML.

Supervised Learning. This method is used to make predictions and requires that data which will be used to "train" the machine is labeled. To achieve supervised learning, "during training, the learner creates an internal representation that represents a generalization of the training data."[38] Since this analysis is currently a manual process, this is a good use case for supervised learning. To ensure effectiveness, strong classification and regression data is needed. Classification refers to specific target features and regression is used when target features are continuous. In this example, equipment features represent the classification data while regression data is accounted for by historical equipment usage. Using historical FELm and Capability data can enable the creation of predictive and more realistic FD scenarios that will shape the FSE. Once the supervised learning is underway, another technique of ML called Evaluation of Learner can be employed to enhance effectiveness.

Evaluation of Learner. This is a learning technique within the ML sphere that focuses on the improvement of performance predicated on historical data. This means that there

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[36] Canada. Department of National Defence. *Capability-Based Planning Handbook*. Ottawa: Chief of Force Development, 2014, 6.
[37] SE, SAP. *Force Element*. SAP Help Portal. SAP SE, Dietmar-Hopp-Allee 16, 69190 Walldorf, Germany, February 4, 2017.
[38] Ibid., 54.

must be an evaluation of how well learner algorithms perform on new data. Evaluating a learner is an important task because it "gives … an indication as to how well a trained model will perform on new data."[39] There are four factors used to assess how well a program can learn: Accuracy (percentage of predictions a model successfully classifies), Precision (correct and incorrect classification instances), Confusion Matrix (predicted values vs actual values), and Receiver Operating Characteristics (true and false positive rates).[40] In this example, the user can run several scenarios with different inputs and expected outcomes to assess how the system performs. With this technique, over time, the system's analysis will become much quicker and more accurate than a specialized human team and as a result can streamline processes such as the maintenance supply chain for future capabilities.

Force Development Scenario Set. While the FSE provides a foundation for CBP, the FDSS scenarios are "developed in order to evaluate the effectiveness of future CAF forces."[41] The process for updating or creating the FDSS encompasses three key steps: extant scenario review, followed by research and administration, and then scenario vector which will includes the selection of critical uncertainties and scenario drivers.[42] During the research and administration phase, the benefits and requirements of new FDSS are assessed prior to engaging a multitude of CAF and Other Government Department (OGD) stakeholders. During the Scenario Vector phase, the following key activities occur: gap analysis, science and technology considerations such as transformational or

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[39] Wlodarczak, Peter. 2019. *Machine Learning and Its Applications*. Vol. First edition. Boca Raton: CRC Press, 98.
[40] Ibid., 98.
[41] Canada. Department of National Defence. *Capability-Based Planning Handbook*. Ottawa: Chief of Force Development, 2014, 20.
[42] Ibid., 22.

disruptive emerging technologies, clustering of similar strategic drivers leading to critical uncertainties, and selection of critical uncertainties that will drive the scenario.[43] From a ML policy integration perspective within CBP, leveraging historical data to identify capability gaps, labelling data to train an algorithm to identify capability gaps, and clustering similar strategic drivers leading to critical uncertainties are all items within the Scenario Vector phase that can strengthen and economize the FDSS through Semi-Supervised ML.

Semi-Supervised Machine Learning. This is a hybrid approach between supervised and unsupervised learning. Consequently, this technique combines or uses specific methods such as labeled data to train an algorithm or clustering to classify and determine feature importance.[44] There are two types of semi-supervised learning approaches: transductive and inductive. Transductive uses labels to infer the labels of unlabeled data. The inductive approach entails deduction of rules from labeled data for unlabeled data. In the context of the FDSS, any data collected that is unlabeled (which could be plentiful as there are multiple data sources with non-uniform datasets) would have the potential to be labelled using either technique of semi-supervised ML. Using ML to label unlabeled data is time-saving and resource effective for CAF strategic planning teams as this type of ML semi can mitigate the need for manual entry by a data scientist. It also comes with a benefit of possibly improving data quality, which could lead to more accurate reporting and predictive capabilities within CBP modeling.

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[43] Ibid., 25.

[44] Wlodarczak, Peter. 2019. *Machine Learning and Its Applications*. Vol. First edition. Boca Raton: CRC Press.

Machine Learning Challenges

The integration of ML into CBP has inherent headwinds. Firstly, ML will initially be resource intensive with costs associated with consultants, data scientists, and infrastructure. Further, there are inherent risks such as limitations "at the strategic level in terms of the bias inherent in the datasets that the machine is utilizing."[45] Secondly, CBP is not a perfect planning tool. It relies on artificial selection[46] and lacks focus in terms of an ill-defined adversary when constructing the FSE and FDSS. Further, adversaries within the CBP construct often lack "connections to any geography, culture, alliance structure or fighting methodology. Instead, the enemy is a collection of weapons systems that we will fight with a … more advanced set of similar systems, in a symmetrical widget-on-widget battlefield on a flat, featureless Earth."[47]

From a ML perspective, this creates issues when a data driven approach to the FSE and FDSS may find it difficult to account for soft power[48] threats, a weapon of choice by near peer adversaries such as Russia and China where "coercive power [is] far more than a collection of capabilities but … the sum of a great deal of other factors, from geography to the relative balance between countries."[49] Thirdly, ML is heavily reliant on quality data which could be a challenge for the CAF regarding the efficacy and condition of historical records for data entry. This will be an obstacle to leveraging ML for CBP given the need to access labelled historical data to conduct evaluation of learner,

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[45] Ayoub, Kareem & Payne, Kenneth (2016) *Strategy in the Age of Artificial Intelligence*, Journal of Strategic Studies, 39:5-6, 808.
[46] Ricks, Thomas E., *The Pentagoner: The Long, Slow Death Of Capabilities-Based Planning*. Foreign Policy. Last modified 5 January 2015.
[47] I Pietrucha, Michael W. *Essay: Capability-Based Planning and the Death of Military Strategy*. USNI News. Last modified 5 August 2015.
[48] Nye, Joseph "Power and Foreign Policy," *Journal of Political Power* 4. no. 1 (April 2011)
[49] Thomas E. Ricks, *The Pentagoner: The Long, Slow Death Of Capabilities-Based Planning*. Foreign Policy, last modified 5 January 2015

supervised, and semi-supervised ML. A way to mitigate this challenge is to ensure ML policy incorporates how historical data is labeled for use in a strategic planning context.

CONCLUSION

ML offers many advantages to strategic planning in a military context but has inherent challenges. It can be resource intensive, pedantic (reliance on quality data), and costly in terms of expertise. Notwithstanding these draw backs, it presents a value proposition as the CAF continues towards a data driven future. ML makes strategic planning smarter; this includes the ability to better assess capability–to-value metrics, conduct gap analysis, optimize supply chains, and create smarter planning scenarios. Moreover, it is a technology that will enable to CAF to "Anticipate, Adapt, and Act."[50] Integrating ML policy into strategic planning and CAF doctrine now will increase defence policy congruence with current planning practices while providing a strong foundation and strategic decision advantages in a data driven future that the CAF will inevitably operate in.

[50] Canada. Department of National Defence. *Strong, Secure, Engaged: Canada's Defence Policy.* Ottawa: Department of National Defence, 2017.

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