



Strategic War Game – Arctic Response

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CF Aerospace Warfare Centre Operational Research

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Abstract

This study considers alternative scenarios for the Canadian Arctic's future. The best and worst scenarios from environmental, economic and political standpoints, as viewed by Canadian Forces Aerospace Warfare Centre personnel, are analyzed using Game Theory. The game consists of three players: the Air Force, the Canadian Government and the Adversary. Possible courses of action are assumed for each of the players, a scoring method is adopted, and the game is executed as a table-top exercise. This yields points of equilibrium from which the Air Force can determine the range of actions that it may take in the defence of Canada's Arctic. This range of actions should provide the Air Force with a general sense of the degree of effort that might be required in the Arctic in coming years.

Résumé

La présente étude porte sur des scénarios possibles pour le futur de l'Arctique canadien. Les meilleurs et pires scénarios des points de vue environnemental, économique et politique, tels que vus par le personnel du Centre de guerre aérospatiale des Forces canadiennes, sont analysés à l'aide de la théorie des jeux. Le jeu met en scène trois joueurs : la Force aérienne, le gouvernement du Canada et l'adversaire. Chaque joueur adopte des plans d'action possibles, on choisit une méthode de pointage, et le jeu se déroule selon le mode d'un exercice sur table. On attribue des points d'équilibre à la Force aérienne à partir desquels elle peut déterminer son rayon d'action dans la défense de l'Arctique canadien. Ce rayon d'action devrait donner à la Force aérienne une idée générale du degré d'effort qui sera peut-être exigé dans les prochaines années dans l'Arctique.

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Executive Summary

Strategic Wargame – Arctic Response

Andrew Billyard; Irene Collin; Heather Hrychuk; DRDC CORA TM 2010-240; Defence R&D Canada – CORA; November 2010.

ES1. The Concept and Doctrine Development Section of the Canadian Forces Aerospace Warfare Center (CFAWC) has been involved in several studies regarding the future, including one study concerning the Canadian Arctic. Two Arctic scenarios were envisioned, representing the extreme (“best” and “worst”) cases, from the point of view of environment (colder or warmer, respectively), political state (co-operative or hostile, respectively) and economic conditions (stable or competitive, respectively). The CFAWC Operational Research and Analysis (OR&A) Team was asked to provide a methodological framework to help objectively assess what these extrema would mean for the Air Force.

ES2. This exercise, and the OR tasking within it, is the first trial of the “strategic war game” capability that CFAWC is currently developing. For this particular exercise, it was decided that a good decision support tool candidate would be Game Theory. In particular, Game Theory was chosen since it allows analysts the ability to explore many possible outcomes of a scenario in a relatively short period, based on a limited number of strategic “courses of action” (COAs).

ES3. The results show that every situation has many possible combinations of COAs, and no particular course of action (COA) is best in every circumstance. For the “worst case”, there are five different equilibrium states. Although the equilibrium state may define the best COA for all of the players, it should be remembered that not all players will necessarily act in their own best interest, especially if this results in another player gaining an equal or greater benefit. However, without greater intelligence as to the players’ behaviour, the equilibrium states are used to predict the probable outcomes. These show that, for both best and worst cases, there is no expectation for the Air Force to require unusual or drastic measures in preparing for the defence of the Arctic in the future. In fact, increasing northern situational awareness is the most that is foreseen.

ES4. This first “strategic war game” has provided insights into the conduct of such exercises, and has established a framework for similar studies. Recommendations are made as to the importance of involving personnel with diverse viewpoints at the outset (prior to the conduct of an exercise) in order to construct an experiment that will answer all of the relevant questions. Thus, the players and COA need be chosen carefully.

ES5. The feasibility of automating the game should be investigated. With automation, input scores might immediately show local and global game equilibria and strategies, thus allowing for a greater exploration of alternatives.

ES6. Overall, the application of Game Theory to this case is considered a success; bearing in mind the uncertainty and the lack of information surrounding the issue, the table-top exercise produced reasonable, high-level results, whereas a more detailed approach would not have had great validity. That is, this study in question involves a period in time in the future (10 years) where it is next to impossible to guarantee any of the proposed variables (other state actors, environmental climate, security environment, resources and technologies); consequently, to model “what if’s” at a tactical level (say by considering specific state actors, particular geographic locations, specific military assets, tactics and procedures) would yield unverifiable results and mislead any reader in regards to the credibility of the results. However, by remaining at a very high level and trying to maintain general trends only, these results should provide the Air Force with a general sense of the degree of effort that might be required in the Arctic in coming years.

Sommaire

Strategic Wargame – Arctic Response

Andrew Billyard; Irene Collin; Heather Hrychuk; DRDC CORA TM 2010-240;

R & D pour la défense Canada – CARO; Novembre 2010.

S1. La section d'Élaboration de concepts et de doctrine du Centre de guerre aérospatiale des Forces canadiennes (CGAFC) a participé à plusieurs études sur le futur, notamment une étude sur l'avenir de l'Arctique canadien. Deux scénarios pour l'Arctique ont été imaginés, représentant des situations extrêmes (meilleurs et pires scénarios), du point de vue de l'environnement (plus chaud et plus froid), politique (collaboration ou hostilité) et des conditions économiques (stable ou concurrentiel). On a demandé à l'équipe d'analyse et de recherche opérationnelle du CGAFC de fournir un cadre méthodologique afin d'aider à analyser objectivement la signification de ces situations extrêmes éventuelles pour la Force aérienne.

S2. Cet exercice, et la recherche opérationnelle qui y est associée, constituent la première mise à l'épreuve du jeu de guerre stratégique que le CGAFC est en train d'élaborer. Pour cet exercice particulier, on a décidé que la théorie des jeux constituait un bon outil d'aide à la prise de décisions. On a retenu la théorie des jeux plus particulièrement parce qu'elle permet aux analystes d'étudier beaucoup de résultats possibles découlant d'un scénario dans une période relativement courte en fonction d'un nombre limité de plans d'action stratégiques.

S3. Les résultats démontrent que chaque situation comporte plusieurs combinaisons possibles de plan d'action et aucun plan d'action particulier n'est idéal en toute circonstance. En ce qui concerne le pire scénario, il existe cinq états d'équilibre différents. L'état d'équilibre peut définir le meilleur plan d'action pour tous les joueurs, mais on doit se rappeler que tous les joueurs n'agiront pas nécessairement dans leur meilleur intérêt, surtout si un autre joueur en retire un avantage égal ou supérieur. Toutefois, sans en savoir davantage sur le comportement des joueurs, les états d'équilibre servent à prédire les résultats probables. Ils démontrent que pour le meilleur comme le pire scénario, on ne s'attend pas à ce que la Force aérienne doit mettre en œuvre des mesures inhabituelles ou radicales dans sa préparation de la défense de l'Arctique dans le futur. En fait, la situation la plus vraisemblable est qu'on augmente la connaissance de la situation du Nord.

S4. Ce premier « jeu de guerre stratégique » a ouvert des perspectives sur la conduite de pareils exercices et a permis d'établir un cadre de travail pour la réalisation d'études similaires. On fait des recommandations sur l'importance de demander les points de vue du personnel dès le début (avant la conduite d'un

exercice) afin de mettre au point une expérience qui répondra à toutes les questions pertinentes. Les joueurs et les plans d'action doivent par conséquent être choisis avec soin.

S5. Il faudrait étudier la possibilité d'automatiser le jeu. En automatisant le jeu, les points d'entrée pourraient immédiatement indiquer l'équilibre du jeu sur le plan local et mondial ainsi que les stratégies, permettant ainsi d'étudier plus en détail les possibilités.

S6. Dans l'ensemble, l'application de la théorie des jeux à ce scénario est considérée comme un succès. Si on se rappelle l'incertitude et le manque d'information entourant la situation, l'exercice sur maquette a donné des résultats raisonnables et de hauts niveaux où une approche plus détaillée n'aurait pas représenté une grande validité. Ceci dit, l'étude en question comporte une période dans le futur (10 ans) et il est pratiquement impossible de garantir une des variables proposées (d'autres acteurs étatiques, la situation climatique, les ressources et les technologies). Par conséquent, la modélisation du « si » au niveau tactique (en considérant des acteurs étatiques particuliers, des lieux spécifiques ainsi que des actifs militaires, des tactiques et des procédures particulières) entraînerait des résultats invérifiables et induirait en erreur tout lecteur en ce qui a trait à la crédibilité des résultats. Cependant, en demeurant à un niveau très élevé et en tentant de conserver uniquement les tendances générales, ces résultats devraient donner à la Force aérienne une idée générale du degré d'effort qui peut être exigé dans l'Arctique au cours des prochaines années.

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1. Introduction

1.1 Background

1. The Concept and Doctrine Development Section of the Canadian Forces Aerospace Warfare Center (CFAWC) has been involved in several studies regarding the future, including one study concerning the Canadian Arctic. Two Arctic scenarios were envisioned, representing the extreme (yet still plausible) cases (“best” and “worst” cases), from the point of view of environment (colder or warmer, respectively), political state (co-operative or hostile, respectively) and economic conditions (stable or competitive, respectively). The CFAWC Operational Research and Analysis (OR&A) Team was asked to provide a methodological framework needed to help objectively assess what these extrema would mean for the Air Force.

2. Indeed, this exercise, and the Operational Research (OR) tasking within it, is the first trial of the “strategic war game” capability that CFAWC is currently developing. In short, CFAWC is developing a high-level table-top exercise programme wherein experts can be assembled in a short period of time to define, articulate and refine strategic level concepts for CFAWC [1]. As a response to this emerging capability, the Defence Research and Development Canada (DRDC) Center for Operational Research and Analysis (CORA)/CFAWC OR&A team in conjunction with the DRDC CORA/Directorate of Air Staff Operational Research (DASOR) have initiated an applied research project (ARP 13rh) which, in part, addresses the need to understand which “strategic level” decision support tools are appropriate for table-top exercises designed for high-level discussions.

3. For this particular exercise, it was decided that a good decision support tool candidate would be Game Theory. Although this was the first time that it has been used within CFAWC, it has already had limited application within DRDC CORA [2-5]. In particular, Game Theory was chosen since it allows analysts the ability to explore many possible outcomes of a scenario in a relatively short period, based on a limited number of strategic “courses of action” (COAs).

1.2 Aim

4. The aim of this study is to determine the range of actions that the Air Force, when it considers itself to be acting in its own best interests, would most likely be required to take in response to combinations of scenario (environmental, economic and political

climate) and counter-action (from Canadian government policies or adversarial actions).¹ Furthermore, the document also assesses how well Game Theory can be used to support these types of table-top exercises.

1.3 Outline

5. A description of Game Theory is provided in Section 2, along with the application of Game Theory to the Arctic scenarios, providing the various assumptions and particulars, scores and results. Section 3 presents the Conclusions and Observations.

¹ While in reality it would not be the Air Force who determines what such responses are (in case of an encroachment of Canadian sovereign territory for example, the Government of Canada would turn to Canada Command, who in turn would task air assets), it is still necessary for the Air Force to be aware of its preferred course of action in a given situation. As a participant in the centralized force development process and mission analysis, the Air Force is often called upon to provide such information, and as such, should have some baseline knowledge to underpin its responses to such queries.

2. CFAWC Strategic War Game

6. This section presents a brief description of Game Theory, which is then applied to the Arctic War Game. The Arctic scenarios are described, followed by the COAs for each player, the scoring system and finally, the results of the exercise.

2.1 Game Theory Overview

7. This section describes Game Theory in general terms; specifics to the game as applied to the Arctic scenarios are contained in Section 2.2. For the first war gaming exercise, n -person non-cooperative Game Theory was chosen as the multi-criteria decision support tool. A brief summary of n -person non-cooperative Game Theory is given here. See Reference 6 for a more formal and complete description of the subject. A “game” in the broad sense is the participation of two or more “players” in a defined scenario. Each player has one or more high level COAs that they will try to accomplish in order to satisfy their goal. In Game Theory, all possible combinations of player actions are considered and for every combination, a score for each player is determined to reflect the preference of combinations from each player’s perspective. For example, if there are three players and each player has four courses of action, then three sets of scores are created for the entire $4 \times 4 \times 4 = 64$ combination set (one set of scores for each player).

8. The next step is for the table-top participants to use these scores to indicate the best course of action (COA) for a particular player when facing a certain combination of actions by the other players; the highest score within that subset indicates that player’s best COA. For instance (carrying on with the example above), consider a specific action of player 2 combined with that of player 3. What is player 1’s best COA against the combined actions of the other players? Because a scoring scheme for player 1 has already been completed for the entire 64 combinations, one simply looks for instances of this particular player 2 – player 3 combination within the larger list (there will be four of them since player 1 has four COAs) and the highest score will represent player 1’s best COA for that combination. It is considered the best (for that combination) because any other choice is at a lower score for player 1.

9. Finally, once the preferred COAs for each player have been computed against each combination of the other players’ actions, one looks for Nash equilibria. These are the specific COA combinations in which each player’s COA is the player’s *best* COA. Simply put, in the equilibrium combination, every player would have to choose a lower score (and therefore less preferred COA) to get out of that equilibrium position. This is equivalent to stating that all players would have to make a choice that is not in their best interest in order to alter the state of the game.

10. It is important to understand what the equilibrium points represent. They do *not* represent an inevitable end-state of the game. What they represent is the state to which players will naturally tend towards due to their own selected preferences. Hence, Game Theory provides a way of estimating the consequence of the players' preferences. That is, one may draw conclusions such as "If you prefer this COA, do not be surprised to find yourself in a situation wherein ..."

2.2 Game Theory Applied to this War Game

11. In this war game, there are three players: the Air Force, the Adversary (described below) and the Government. It is assumed that the three players are non-cooperative; that is, "cooperation among some or all of the players may be forbidden... by the rules of the game" [Reference 1, Chapter VIII]. The key word here is "may"; in the long run the Air Force will take direction from Canada Command who in turn takes direction from the Government. However, if a cooperative version of the game was played, then the Government-Air Force players would effectively merge and there would be no room for the Air Force to understand its own role in the future force development arena. Although the non-cooperation game may appear too unrealistic considering that the Air Force and the Government would typically work in concert, it allows the table-top participants to reflect on any disparity that could arise in reality between these two players; this rule allows the Government in the game to act in ways contrary to the good of the Air Force and vice versa. An example would be for the Government to decrease "Arctic Funding" when existing policies and mandates may insist the Air Force maintain its current Arctic capabilities (status quo). Hence the two are at odds; the strategic COA to maintain status quo for the Air Force is at odds with the Government's COA to reduce Arctic Funding.

12. Two scenarios are considered in this war game, the details of which follow. These scenarios were drafted by CFAWC personnel in response to a requirement set by the Chief of the Air Staff (CAS). In looking at the future Arctic environment in which the Air Force would operate, the CAS desired to look 'outside the box' or beyond the traditional thinking within the department. Instead of looking to the most plausible scenario for Air Force engagement in the Arctic in 2020, the CAS requested two alternative scenarios be developed: the 'best case' and 'worst case.' While still within the realm of plausibility these scenarios were intended to provide an alternative, less likely future.

2.3 Best Case Scenario

2.3.1 Scenario Particulars

13. In the best case scenario, the Arctic will be an area of decreased activity, articulated as a “frozen hinterland.” In this scenario the Arctic climate remains frozen, with the potential for decreasing temperatures, extending even to a return to a mini-ice age. While unlikely, this was deemed plausible as the Canadian Arctic’s mean temperature has stabilized and begun to cool. Given this climate, the Northwest Passage does not become a practical transport route and very few challenges to Canadian sovereignty have occurred. Good governance and cooperation prevail, and accordingly, the Government has few reasons to deploy CF assets, including the Air Force in the North. Most Arctic intelligence, surveillance and reconnaissance (ISR) is accomplished by space and near-space assets; however, these requirements on the whole have been decreasing. While interest in Northern commodities such as oil and gas are still prevalent, the costs to extract them from a frozen Arctic have made this process economically unfeasible. Costs, coupled with the harsh weather conditions, have resulted in a lack of economic development.

2.3.2 Variables

14. To apply game theory to this scenario, two players, each with a range of actions available to them, were determined in the table-top exercise: the Air Force and the Canadian Government. Unlike the ‘worst case’ scenario (to follow), the particulars of this scenario do not result in the need for a third player (the Adversary). However, it is understood that adversaries may exist, but their only credible threat would be to build Arctic capabilities in their own sovereign state in anticipation of exploiting the Arctic (which leads the Government player to continue to engage in diplomatic talks; see below). As such the game is two-dimensional in nature and lends itself easily to showing how the game theory was implemented.

15. Each player was assigned realistic COAs in accordance with the details of the scenario. These COAs were developed by the Operational Research team and then reviewed and ratified by CFAWC personnel. For the Air Force, the decided COAs were:

- a) Maintain the Status Quo;
- b) Decrease Situational Awareness;
- c) Decrease Presence; and,
- d) Decrease Force Application.

16. For *Maintain the Status Quo*, the Air Force maintains the level of effort it currently devotes to its Arctic areas of interest, missions and capabilities.
17. For *Decrease Situational Awareness*, the Air Force decreases its surveillance capabilities. Whereas information is collected to increase situational awareness, analysis does not necessarily occur to increase situational understanding. The decrease may entail the Air Force divesting itself of equipment or simply not undertaking as many missions as it has been previously engaged in.
18. For *Decrease Presence*, the Air Force limits its presence in the Arctic. This COA includes decreasing a variety of possible options such as sovereignty patrols or overt surveillance capabilities.
19. Finally, for *Decrease Force Application*, the Air Force either divests itself of its Arctic force application capabilities, such as interception capabilities, or decreases the number of force application missions it undertakes.
20. These Air Force actions are summarized in Table 1.

Table 1: Air Force Actions -- Best Case Scenario

Air Force Actions	Explanation
Maintain the Status Quo	Current level of effort (missions, capabilities)
Decrease Situational Awareness	Lesser surveillance capabilities (equipment, missions)
Decrease Presence	Limited Arctic patrols, monitoring, etc.
Decrease Force Application	Lesser interception capability, fewer missions

21. Similarly, the Canadian Government in the game has been assigned three COAs that it may undertake:
- a) Maintain the Status Quo;
 - b) Decrease Arctic Funding; and,
 - c) Exercise Diplomacy.
22. For the first of these COAs, *Maintain the Status Quo*, the Government's policies, actions, activities and funding² in the Arctic remain consistent with those of 2009.
23. For *Decrease Arctic Funding*, the Government places less emphasis on the North, and accordingly, has decreased funding. This could entail more limited military capabilities (not necessarily Air Force capabilities) or decreased funding and emphasis placed upon Northern inhabitation, as well as social and economic development.

² Relative to other federal expenditures. This is not saying that the current dollar value (\$x) for Arctic funding will be the same used in 2020.

24. For *Exercise Diplomacy* the Government continues to engage in the international arena (e.g., United Nations Convention on the Law of the Sea) to maintain dialogue. It should be noted that this COA does not achieve a specific goal of redefining boundaries. Rather, the Canadian Government is in the process of making diplomatic overtures, the outcome of which is not necessarily known. This COA is used to reflect the fact that if any adversaries were building Northern capabilities (e.g., arctic mining capabilities) in their own sovereign state, they are not a direct threat to Canadian sovereignty but would be the impetus for the Canadian Government to engage in the international arena to ensure that legal boundaries are set.

25. These Canadian Government actions are summarized in Table 2.

Table 2: Canadian Government Actions -- Best Case Scenario

Canadian Government Actions	Explanation
Maintain the Status Quo	Current policies, actions, activities, funding
Decrease Arctic Funding	Includes funding for Air Force, settlements, development
Exercise Diplomacy	Engagement in international dialogue

2.3.3 Scoring System

26. For this scenario, there are only 12 unique combinations of Air Force and Government COAs; such a small number allows one to easily keep track of and validate the preferences of each player. As such, the scoring system was a simple scale of integers from -3 (worst) to 3 (best).

- 3 - best (Best Case)
- 2 - better
- 1 - good

- 0 - neutral

- 1 - bad
- 2 - worse
- 3 - worst (Worst Case)

27. For the Air Force, the best case would be characterized by the retention of capabilities that are relevant to the security environment dictated by the scenario or by the divestiture of those capabilities that are not required. Alternatively, the worst case would be characterized by decreasing those relevant capabilities or by retaining those which are not required considering the Arctic security environment described in the scenario.

28. For the Government, the best case would be characterized as that which table-top participants consider the most appropriate response of the Government in light of both the scenario and the other player's COA. This may mean decreasing Arctic funding in some situations, or engaging in diplomacy in others. The worst case would be that in which the Government's response does not adequately meet the challenge posed by the scenario, or where the Government's response is too great.

29. For example, in a case in which the Air Force maintains the status quo, it would be more preferential for the Government to decrease Arctic funding, therefore resulting in the Government being given a score of +2. The reasoning is that, in this scenario, engaging in diplomacy is unwarranted and maintaining the status quo entails unnecessary funds being spent. By comparing with the alternatives, the Government's preference would be to decrease Arctic funding.

2.3.4 Results Matrix

30. Table 3 depicts the game theory results for the Best Case Scenario. Each cell contains two numbers: the first is the Air Force's preference for this combination of actions and the second is the Government's preference. For example, the first cell contains "(1, -1)", meaning that the Air Force would consider it good (+1) that the Air Force maintains Status Quo whilst the Government maintains Status Quo, whereas the Government would consider this combination bad (-1).

31. Note that the only blue cell in this table represents the only Nash equilibrium; this is the combination of Air Force decreasing force application capabilities while the Government pursues diplomacy. This example shows clearly why this is an equilibrium point. The Air Force preference is high for this option (+3) as is the Government's, though to a lesser extent (+1). However, for the Government's Pursue Diplomacy action, the Air Force will have a lesser score if it chooses any other COA for itself (vertical direction in the table). Similarly, for the Air Force's Decreased Force Application, the Government will have a lesser score if it chooses any other COA for itself (horizontal direction in table).

Table 3: Results Matrix for the Best Case Scenario

	Government: Maintain Status Quo	Government: Decrease Arctic Funding	Government: Pursue Diplomacy
AF: Maintain Status Quo	(1, -1)	(-1, 2)	(0, 1)
AF: Decrease Sit. Aware. Capabilities	(-1, -2)	(-2, -1)	(1, 1)
AF: Decrease Presence Capabilities	(3, -2)	(3, -1)	(2, 1)
AF: Decrease Force Application Capabilities	(2, -2)	(2, -1)	(3, 1)

Legend:

- Number pairs (x, y) represent the ranking preference of the Air Force and Government, respectively, for each combined COA.
- Bold numbers indicate the player’s most preferred COA in regards to the other player’s COA. The direction of comparison for one (x, y) is indicated in this figure by dashed circles and lines (e.g., for the Government’s “Status Quo” [1st column], of the 4 possible actions by the Air Force, the 3rd one is most preferable [3rd row]).
- Blue cells represent the Nash equilibrium – both players would have to choose a less preferable COA to get out of this equilibrium.

32. In order to demonstrate how this is an equilibrium point, consider the following. Suppose at some time the Air Force and Government are maintaining Status Quo (top left cell). If the Government chooses to change its COA, it would (in the table) move horizontally from “Status Quo” to “Decrease Arctic Funding” since it is more preferable for the Government (scores a “+2” rather than Status Quo’s “-1”). The situation is now the top middle cell. At this point the Air Force would change its COA to “Decrease Presence” (+3) since that would be more preferable than “Status Quo” (-1). Consequently, the scenario has moved to the second-last cell in the middle column. At this point, the Government would change its COA to “Diplomacy” since it is now more preferable (+1) than “Decrease Arctic Funding” (-1) and so the scenario moves to the second last cell in the right-most column. Finally, the Air Force would change its COA to the more preferable “Decrease Force Application Capabilities” (+3), and the scenario moves to the blue Nash equilibrium. At this point, neither player can move to a more preferable COA. The only way that they can do so is to move to a less preferable option and hope that the other player changes its COA. However, for this scenario, there is only one equilibrium; regardless of where they start in the table, if both players keep changing their COA to a more preferable one, they will inevitably end up in the blue cell of this table.

33. Finally, it should be noted that the Government never scored a “3” (best case) in any COA. This is merely due to the artefact that the scale and the scale meanings were

developed before (and independent of) the COAs. Hence, once the game started, the SMEs never felt that there was a “3” for the Government. However, since the importance of this game is in the *relative* rankings and not the rankings themselves, this anomaly does not imply any deficiency in the end results. What it suggests is that a 7-point scale was too fine for the Government player for this exercise and that (for instance) a 6-point scale would have been sufficient.

2.4 Worst Case Scenario

2.4.1 Scenario Particulars

34. In the worst case scenario, the Arctic will be an area of increased activity, articulated as a “gold rush.” This scenario is characterized by increased global warming, which has led to continuous melting of sea ice and rising sea levels. In turn, the Arctic areas once deemed impassable are now appealing routes for international shipping, along with various illegal activities such as human trafficking. While the Canadian Government continually declares the Northwest Passage to be within its territorial waters, its limited capability to enforce its sovereignty has resulted in frequent intrusions into this sovereign territory. Cooperation between Arctic nations is limited, while tensions between Russia and the West over Arctic political boundaries have developed into a serious crisis. Referred to as Cold War II, NORAD assets are constantly tested by Russian manned and unmanned vehicles, while submarines and nuclear-powered icebreakers have violated Canada’s territorial waters. Further, the warmer climate has increased human activities related to mineral and oil exploration, fishing and tourism. Unfortunately, the rush to extract oil and other lucrative resources has prompted many corporations to show complete disregard for Canadian laws and environmental concerns.

2.4.2 Variables

35. To apply game theory to this scenario, three players, each with a range of actions available to them, were determined: (in no particular order) the Air Force, the Adversary (who could be a competing nation or a non-state entity such as a criminal organization or corporation) and the Canadian Government. While the environment has a large role to play in influencing the range of actions available to these players, it was not included as an independent actor, as although it may undertake various COAs, it does not exhibit any preferences of action, unlike the other actors.

36. Each player was then assigned four realistic COAs given the details of the scenario. In the case of the Air Force the first COA is *Maintain Status Quo*. Here, the Air Force maintains the level of effort it currently devotes to its Arctic areas of interest, missions and capabilities.

37. The second COA available to the Air Force is *Increase Situational Awareness*. Here the Air Force’s surveillance capabilities are increased; however this is limited to covert surveillance. Information is collected to increase situational awareness, although analysis does not necessarily occur to increase situational understanding. This increase may entail the acquisition of new equipment to provide increased capabilities or the deployment of current equipment on more missions to increase the capability.

38. *Increase Presence* is the third COA. This COA includes a variety of possible options such as increased sovereignty patrols, overt surveillance capabilities or the establishment of an Air Force base in the North. However, these capabilities are limited in that they demonstrate an Air Force presence, without interception or escort capacities. For example, this might include the installation of monitoring platforms, such as tethered aerostats, without the provision for reacting to anything that may be detected.

39. Finally, the fourth COA available to the Air Force is *Increase Interception and Engagement*. Here the Air Force increases its capabilities to intercept and engage with other actors (military or civilian) in the Arctic or it enhances its current capabilities. This is not limited solely to escort capabilities but also includes kinetic capabilities.

40. These Air Force actions are summarized in Table 4.

Table 4: Air Force Actions – Worst Case Scenario

Air Force Actions	Explanation
Maintain the Status Quo	Current level of effort (missions, capabilities)
Increase Situational Awareness	Greater surveillance capabilities (equipment, missions)
Increase Presence	More Arctic patrols, surveillance, or establishment of base
Increase Interception/Engagement	Increased/enhanced escort/kinetic capabilities

41. The Adversary was also assigned a range of actions that it might undertake in the worst case Arctic scenario. The first of these is described as *Encroach on/Exploit Canadian Territory*. Here non-state or state-sponsored actors encroach on Canadian territory or waterways to exploit resources, or utilize territory or waterways for transit during illicit activities. Non-state actors could be Canadian nationals acting outside Canada’s interests, or civilians from other nations.

42. The second COA available to the Adversary is *Respect International Treaties Due to Canadian Actions*. Here, other nation states or non-state actors respect Canadian sovereignty, despite their Northern interests, due to the actions of the Air Force or Canadian Government. It assumes that others want to encroach on Canadian territory but their freedom of action is constrained due to Canadian activities.

43. The third COA is *Legally Redefine Political Boundaries (in the Adversary's Favour)*. Here, other nation states attempt to end territorial disputes through international dialogue and are in the process of successfully redefining political boundaries in alignment with their desires.

44. The final COA available to the Adversary is *Increase Northern Capabilities*. In this COA other nations (whether they be friendly or hostile) are engaged in the building of military and non-military Arctic capabilities.

45. These Adversary actions are summarized in Table 5.

Table 5: Adversary Actions – Worst Case Scenario

Adversary Actions	Explanation
Encroach on/Exploit Canadian Territory	Includes invasion/illicit use of land/water, exploitation of resources
Respect International Treaties	Implies the desire to encroach, deterred by Canadian actions
Legally Redefine Political Boundaries	Through dialogue, international courts, against Canada
Increase Northern Capabilities	Building/accumulating military/non-military Arctic capabilities

46. Like the Air Force and the Adversary, the Canadian Government has been assigned a range of actions that it may undertake. The first of these COAs is *Maintain the Status Quo*. Here the Government's policies, actions, activities and funding in the Arctic remain consistent with those of 2009.

47. The second COA available to the Government is *Threaten Actions/Posturing*, in which the Government increases its position in relation to the Adversary's activities. While this could be political posturing (rhetoric), it can also include increasing Arctic patrols or basing as well as funding military Arctic capabilities. These could be single service or joint capabilities, but are not necessarily Air Force capabilities.

48. The third Government COA is *Increase Treaty Dialogue*. In this situation the Government increases its engagement in international dialogue as an attempt to resolve territorial disputes. It should be noted that unlike the Adversary's third COA, this COA is not defined as achieving a specific goal of redefining boundaries. Rather the Canadian Government is in the process of making diplomatic overtures, the outcome of which is not determined.

49. The final COA available to the Government is *Increase Northern Immigration and Development*. In this situation the Government is placing greater emphasis on, and

funding towards, Northern inhabitation, and social and economic development. These developments are not related to military assets.

50. These Canadian Government actions are summarized in Table 6.

Table 6: Canadian Government Actions – Worst Case Scenario

Canadian Government Actions	Explanation
Maintain the Status Quo	Current policies, actions, activities, funding
Threaten Actions/Posturing	Includes increased Arctic patrols, basing, funding or political talks
Increase Treaty Dialogue	International dialogue
Increase Northern Immigration/Develop.	Funding settlements, social/economic development (non-military)

2.4.3 Scoring System

51. For this scenario, there are 64 unique combinations of Air Force, Adversary and Government COA. Therefore, the simple “worst” to “best” scoring scheme used in the previous scenario would prove to be hard to manage. For instance, there could be many combinations that the Air Force would consider “better”, but some “better” could mean different things to different combinations. Effectively, one would have to do a pair-wise comparison of all the combinations to determine if one is better, the same, or worse than the other. This would entail $64 \times 63 = 4,032$ pair-wise comparisons for each player, which is unmanageable in a one-day workshop. Instead, it was determined that for each player a unique meaning would be assigned to the integer scores. Consequently, each combination could be assigned a score based on a logical argument, independent of how the other combinations scored. Descriptions of the scores, as applied to each player, are provided in the following paragraphs.

2.4.3.1 Air Force

52. A positive ranking for the Air Force indicates that the situation is in its preference, achieving a favourable or desirable mission outcome. However, some situations, such as those with no or limited cost increases, are more desirable than others. For example, in a situation in which the Adversary respects international treaties and the Government maintains the Status Quo, the tabletop exercise determined that it is preferable for the Air Force to have increased surveillance than to have increased interception. Whereas both COAs achieve the desired result (the Adversary respecting Canadian sovereignty), the costs associated with increased surveillance (both in terms of level of effort and monetary costs) are limited when compared to those associated with increased interception. Further, increased interception capabilities are unnecessary when

the Adversary respects the sovereign territory. Positive rankings are articulated as follows:

- +4 Achieving mission/desired outcome without any increased costs, Very appropriate capability increase given circumstances
- +3 Increased Surveillance/Situational Awareness, Achieves favourable/desired mission outcome, Limited costs, Very appropriate capability increase given circumstances
- +2 Increased Presence, Achieves favourable/desired mission outcome, Medium costs, Very appropriate capability increase given circumstances
- +1 Increased Interception, Achieves favourable/desired mission outcome, Large costs, Appropriate capability increase given circumstances
- 0 Neutral Impact/Others actions do not affect

53. A negative value for a ranking implies that the situation does not achieve an outcome that is favourable to the Air Force. For example, in a situation in which the Adversary is encroaching on Canadian borders or exploiting Canadian resources, despite the Air Force's increased interception capabilities and the Government's increased diplomacy, the Air Force would receive a rank of -3. This is due to the fact that the Air Force's actions do not achieve a favourable mission outcome (forcing the encroachment to cease) at a large cost (the Adversary continues to engage in these actions despite the Air Force's increased capability). Therefore such a situation would not be in the Air Force's favour. The negative rankings are described as follows:

- 1 Increased Surveillance/Situational Awareness, Does not achieve favourable mission outcome and with limited costs, Inappropriate capability increase given circumstances
- 2 Increased Presence, Does not achieve favourable mission outcome, with medium costs, Very inappropriate capability increase given circumstances
- 3 Increased Interception, Does not achieve favourable mission outcome and with large costs, completely inappropriate capability increase given circumstances

2.4.3.2 Adversary

54. The Adversary has been assigned rankings which vary between -3 and +3. A positive ranking indicates that the Adversary is able to achieve its objective or mission, although its ability to do so may be hampered by the risks involved (in relation to the Air Force's or Canadian Government's actions). For example, in the case in which the Adversary, such as a country, continues to encroach, or in the case of a commercial entity, continues to exploit Canadian resources despite the Air Force's increased interception capabilities and the Canadian Government's increased diplomatic efforts, the Adversary would be given a rank of +1. Here the Adversary can achieve its mission of encroachment, although it may be with loss, either by being intercepted or by facing

repercussions in diplomatic circles. However, these risks and losses are insufficient levers to curtail the Adversary's ambitions.

- +3 Mission Success, Unhampered
- +2 Mission Success, With impediment(s) or risks
- +1 Mission Success, With loss, future loss

- 0 Neutral Impact/Others' actions do not affect

55. A negative ranking indicates that the Adversary's freedom of action is limited or curtailed completely, and complemented with a range of potential repercussions. For example, in the case in which the Adversary desires to encroach, but is forced to respect international treaties, a negative ranking is appropriate.

- 1 Actions Limited, Limited repercussions (slap on the wrist)
- 2 Limited Freedom of Action, Large scale/Future repercussions
- 3 Mission Failure/ No Freedom of action

2.4.3.3 Government

56. In the case of the Government, rankings are composed of two variables, the associated costs and the achievement of desired results. Costs for the Government are not only those monetary funds that are expended, but also intangible costs such as potential embarrassment or loss of votes. For the Government, a situation whereby the status quo is maintained and the Adversary respects international agreements would warrant a ranking of +3. Here there is no cost to the Government and the desired result, maintenance of sovereign territory, is achieved.

- +3 No cost, achieves desired results, Most appropriate action given circumstances
- +2 Limited costs, achieves desired result, Very appropriate action given circumstances
- +1 Large costs, achieves desired results, Appropriate action given circumstances

- 0 Neutral Impact/Others' actions do not affect

57. Alternatively, in a situation in which the desired result is not achieved, a negative ranking is applied. This ranking is relative to the costs involved on the Government's behalf. For example, in a situation in which the Adversary is encroaching, the Air Force is increasing interception, and the Government has increased Northern immigration and development, a -3 is warranted due to the large monetary funds being expended. However, in a situation in which the other players pursue the same COA and the Government maintains the status quo, a -3 is also applicable. This is due to the fact that large costs, in terms of embarrassment and power projection, would be incurred if

Canada's territory was being encroached and the Government did not respond. While this may not be a realistic possibility, it needs to be considered nevertheless, and indeed through the results of the game was demonstrated to be an unlikely occurrence.

- 1 No costs, does not achieve desired results, Inappropriate action given circumstances
- 2 Limited costs, does not achieve desired results, Very inappropriate action given circumstances
- 3 Large costs, does not achieve desired results, Most inappropriate action given circumstances

2.4.4 Results Matrix

58. Table 7 represents the results matrix for the Worst Case Scenario. Since this scenario's game is three-dimensional, a little creativity must go into displaying the entire dataset in a two-dimensional representation. Within this table, the unit cells contain three numbers in the format "(x, y, z)": the first is the Air Force's preference score for the combination of actions, the second is the Adversary's preference score and the third is the Government's preference score. To deduce the course-of-action combination structure within this table, one starts with the heavy grey dividing lines. These are used to highlight the rows and columns denoting (respectively) the Air Force's COAs and the Adversary's COAs; the intersection of which yields a solid grey "super" cell. Within each super cell are four unit cells divided by lighter, dashed lines, which represent each of the Government's COA. The first super cell in Table 7 includes red footnotes that indicate, in a legend below the table, which unit cell corresponds to which Government COA.

59. Light circles and dashes are shown to demonstrate how the most preferred COA for each player (bold numbers in table) is determined against each combined COA of its opponents. For example, in order to determine the Air Force's best COA for a unique combination of Adversary-Government COA, the first numbers of triplets must be compared along a column (fixed Adversary COA), skipping every other row (so that it is always in the same relative unit cell representing a fixed Government COA); see the blue dashed circles and lines in Table 7. Similarly, in order to determine the Adversary's best COA for a unique combination of Air Force-Government COA, the second numbers of the triplets must be compared along a row (fixed Air Force COA), skipping every other column (so that it is always in the same relative unit cell representing a fixed Government COA); see the red dashed circles and lines in Table 7. Finally, in order to determine the Government's best COA, the third numbers in the triplets within a super cell (the intersection of the Air Force COA and the Adversary COA) are compared); see the green dashed circles and lines in Table 7.

Table 7: Results Matrix for the Worst Case Scenario

	Adversary – Encroach on Canadian Territory	Adversary – Respecting International Treaties	Adversary – Legally Redefining Agreement	Adversary – Increase Northern Capabilities
AF - Maintain Status Quo	(-1, 3, -2) †	(-1, 2, -2) ‡	(4, -3, 3)	(4, -3, 1)
	(-1, 2, -2) *	(-1, 2, -3) §	(4, -3, 2)	(4, -3, -3)
AF – Increase Situational Awareness Capabilities	(-1, 2, -1)	(-1, 2, -2)	(3, -3, 3)	(3, -3, 1)
	(-1, 2, -1)	(-1, 2, -3)	(3, -3, 2)	(3, -3, -3)
AF – Increase Presence Capabilities	(-2, 2, -2)	(-2, 1.5, -2.5)	(2, -3, 3)	(2, -3, 1)
	(-2, 1.5, -1)	(-2, 1.5, -3)	(2, -3, 2)	(2, -3, -3)
AF – Increase Force Application Capabilities	(-3, 1, -3)	(-3, 1, -2)	(1, -3, 3)	(1, -3, 1)
	(-3, 1, -2)	(-3, 1, -3)	(2, -3, 2)	(1, -3, -3)

† Gov't – Maintains Status Quo	‡ Gov't – Increase Posturing
* Gov't – Increase Dialogue	§ Gov't – Increase North Imm. & Devel.

Legend:

- Number triplets (x, y, z) represent the ranking preference of the Air Force, Adversary and Government, respectively, for each combined COA.
- Bold numbers indicate the player's most preferred COA in regards to each combination of the other players' COA (the dash circles and lines indicate the direction along which each player considers their preferences).
- Blue cells represent the Nash equilibrium – each player would have to choose a less preferable COA to get out of this equilibrium.

60. Note that there are five Nash equilibria to this table, as summarized below.
- Air Force Maintains Status Quo
Government Increases Dialogue
Adversary Building Northern Capability outside Canadian sovereignty.
 - Air Force Maintains Status Quo
Government Increases Dialogue
Adversary Appears to be Successfully Redefining Political Boundaries.
 - Air Force Increases Situational Awareness
Government Increases Dialogue
Adversary is encroaching on Canadian Borders.

- d) Air Force Maintains Status Quo
Government Increases Dialogue
Adversary is encroaching on Canadian Borders.
- e) Air Force Maintains Status Quo
Government Maintains Status Quo
Adversary is encroaching on Canadian Borders.

61. Again, all equilibrium points represent an end state that the players tend to move towards. Which equilibrium point that they tend towards depends on how the game is played.

62. It should be noted that there are three instances in this table where a half score is used (e.g., 1.5, -2.5, etc.). These scores arose because the SMEs felt that the meaning of the two bracketing ranks did not apply, but that the actual meaning was somewhere in between. For instance, in one COA, the adversary had a score of 1.5 because the SMEs felt that “mission success with loss” (rank of 1) for the adversary was too weak of a statement (with respect to the same rank used in other COAs) whereas “mission success with impediments or risks” (rank of 2) was too strong of a statement (again, with respect to the same rank used in other COAs). However, one should never interpret the 1.5 as the exact difference between the two. Because this game relies solely on the relative rankings, a value of 1.3 (say) could have been equally used. Because this refinement was required only three times, it was deemed unnecessary to re-evaluate the game with a ranking system with more than the current 7 points used for the Adversary (for instance, one could have created a 9-point system, wherein all current “2” ranks would become “3” and the “1.5” would become “2”; however, the relative rankings would not change and the end results would be the same).

2.4.4.1 Bifurcation Example

63. That the players can tend towards separate equilibrium points depending on how the game is played is illustrated here. Consider Table 8 below. Suppose that the players are at the bottom left unit cell (circled in green). Here, the Air Force has increased its force application in the North, the Adversary is encroaching on Canadian borders and the Government is increasing its international treaty dialogue. This is the best COA for the Government, so it would not likely change its stance. However, this is not the best COA for the Air Force or the Adversary and so they will tend to choose another COA that better suits them.

64. If the Adversary moves first (they are taking a loss at encroachment and the Air Force does not seem to be letting up on its force application), then its best COA is to go about legally redefining boundaries in its favour (dashed blue line in Table 8). Treaty

dialogue is still the Government's best COA, but now the Air Force would choose a better COA (investing in force application with no threat is costly). As a result, maintaining 2009 Status Quo would seem the best COA for the Air Force, and the game has reached equilibrium.

65. If the Air Force moves first (their force application does not seem to be deterring encroachment), then their best COA is either to increase situational awareness or revert to maintaining the 2009 Status Quo ("cheapest option"), as indicated by the red dashed lines in Table 8. For either choice, this is the best COA for the other two players and so the game has reached equilibrium.

Table 8: Results Matrix for the Worst Case Scenario – Bifurcation Example

	Adversary – Encroach on Canadian Territory	Adversary – Respecting International Treaties	Adversary – Legally Redefining Agreement	Adversary – Increase Northern Capabilities				
AF – Maintain Status Quo	(-1, 3, -2) [†]	(-1, 2, -2) [‡]	(4, -3, 3)	(4, -3, 1)	(0, 3, -3)	(0, 3, -2)	(-1, 3, -1)	(0, 2, -1)
	(-1, 2, -2) [*]	(-1, 2, -3) [§]	(4, -3, 2)	(4, -3, -3)	(0, 2, -1)	(0, 2, -3)	(0, 2, 0)	(-1, 3, -3)
AF – Increase Situational Awareness Capabilities	(-1, 2, -1)	(-1, 2, -2)	(3, -3, 3)	(3, -3, 1)	(-1, 3, -3)	(-1, 3, -2)	(-1, 3, -1)	(0, 2, -1)
	(-1, 2, -1)	(-1, 2, -3)	(3, -3, 2)	(3, -3, -3)	(-1, 2, -1)	(-1, 2, -3)	(-1, 2, 0)	(-1, 3, -3)
AF – Increase Presence Capabilities	(-2, 2, -2)	(-2, 1.5, -2.5)	(2, -3, 3)	(2, -3, 1)	(-2, 3, -3)	(-2, 3, -2)	(-2, 3, -1)	(-2, 2, -1)
	(-2, 1.5, -1)	(-2, 1.5, -3)	(2, -3, 2)	(2, -3, -3)	(-2, 2, -1)	(-2, 2, -3)	(-2, 2, 0)	(-2, 3, -3)
AF – Increase Force Application Capabilities	(-3, 1, -3)	(-3, 1, -2)	(1, -3, 3)	(1, -3, 1)	(-3, 3, -3)	(-3, 3, -2)	(-3, 3, -1)	(-3, 2, -1)
	(-3, 1, -2)	(-3, 1, -3)	(2, -3, 2)	(1, -3, -3)	(-3, 3, -1)	(-3, 2, -3)	(-3, 2, 0)	(-3, 3, -3)

[†] Gov't – Maintains Status Quo	[‡] Gov't – Increase Posturing
[*] Gov't – Increase Dialogue	[§] Gov't – Increase North Imm. & Devel.

Legend:

- Number triplets (x, y, z) represent the ranking preference of the Air Force, Adversary and Government, respectively, for each combined COA.
- Bold numbers indicate the player's most preferred COA in regards to each combination of the other players' COA (the dash circles and lines indicate the direction along which each player considers their preferences).
- Blue cells represent the Nash equilibrium – each player would have to choose a less preferable COA to get out of this equilibrium.

3. Conclusions and Observations

3.1 Conclusions

66. As shown in the results matrices, every situation has many possible combinations of COAs, and no particular COA is best in every circumstance. The “worst case” matrix shows five different equilibrium states. However, as previously stated, an equilibrium does not necessarily represent the end state of the whole scenario. Although the equilibrium state may define the best COA for all of the players, it should be remembered that not all players will always act in their own best interest, especially if this results in another player gaining an equal or greater benefit. However, in the absence of more robust analysis of whether player 1 (for instance) would strategically choose not to pursue its best COA, the analysis here clearly demonstrates what the end state would typically be if every player chooses their most preferred COA.

67. Best Case: The matrix results show that, in this case, the system tends towards the solution that the Government will continue to engage in treaty dialogues to ensure other nations and non-state players continue to respect Canada’s border claim, while the Air Force divests itself of force application capabilities due to lack of use and deemed unnecessary expenditure.

68. Worst Case: There are five potential end states to this scenario.

1. The Adversary does not encroach on Canadian claimed boundaries, but is building northern capabilities outside Canadian Sovereignty, which causes the Government to increase its treaty dialogue. Because there is no imminent threat to Canadian sovereign borders, the Air Force maintains its 2009 status quo.
2. The Adversary appears to be successfully redefining political boundaries, which causes the Government to increase its treaty dialogue. Because there is no imminent threat to Canadian sovereignty, the Air Force maintains its 2009 status quo.
3. The Adversary continues to successfully encroach on Canadian borders and the Air Force increases its situational awareness capability in the North. The Government continues to increase its treaty dialogue.
4. The Adversary continues to successfully encroach on Canadian borders, which causes the Government to increase its treaty dialogue. The Air Force maintains status quo.

5. The Adversary continues to successfully encroach on Canadian borders, and both the Government and Air Force maintain status quo, most likely due to limited success and budgetary constraints.

69. Thus, these end-states show that the most extreme course of action for the Air Force would be to increase its northern situational awareness. Therefore, there is no expectation for the Air Force to require unusual or drastic measures in preparing for the defence of the Arctic in the future.

3.2 Observations

70. In reflecting on this war game, certain practices and procedures can be identified as critical to the success of future war games. As well, it is recommended that certain questions be asked prior to the planning and execution of any war game. These practices and questions are discussed in this section.

71. First, it is imperative that all of the relevant parties be included in the initial scenario development for the war game, as well as the determination of the strategic courses of action and the players involved. The scenarios should cover the range of conditions that may produce different effects or outcomes. In addition to the worst and best outcome, it might be illuminating to consider variations on the worst outcome. Involving a greater diversity of personnel at the start may also result in a greater or more plausible variety of courses of action. Some of these courses of action may be so similar as to be combined, whereas others may provoke more extreme or interesting reactions by the other players, and be worthy of consideration. Even the choice of players may be expanded, with input from dissimilar game planners, to include those who might have an unexpected effect on the outcomes. The goal is to explore as many aspects of the war game as possible.

72. Beyond this it is of key importance that the role of the war game in the larger force development process, both within the Air Force and the centralized system, be clearly established. In this instance the purpose within the Air Force system is fairly clear: the game serves as one portion of the yearly “Vector Check” of the Air Force Campaign Plan,³ and an initial trial in the path towards developing a future war gaming capability. However, the relationship between it and the broader, centralized force development process and requirements articulated by the force employers is ambiguous. While this was the first trial of an emerging capability, such uncertainty is

³ Each year since 2007 the CFAWC or the Directorate of Air Strategic Plans has undertaken a ‘Vector Check’ aiming to assess the validity of the Campaign Plan that is in annex to the Air Force Strategy. Each Vector check has been undertaken in a different manner, but all aim to assess whether the Campaign Plan will allow the Air Force’s force development to adequately meet the capability requirements ten years in the future.

understandable, however it is an oversight that should be overcome in future war games. To begin to articulate this relationship, the question of why the Air Force requires such a capability must first be answered. As an organization that augments the centralized force development process, the Air Force is often called upon to give subject matter expertise and advice, and as such, there should be a process for developing advice. The degree to which the Air Force need maintain a resident capability to develop expertise, tempered by budgetary, level-of-effort and manpower considerations, will be determined in the future. Clearly articulating such rationales and broader linkages would likely provide greater context for future war games and better understanding of the impact of subsequent results, as well as assisting the Air Force in becoming more familiar and integrated with the centralized force development process.

73. Involving additional personnel or subject-matter experts in the development of the war game will require extra time during the planning phase, prior to the execution of the war game. Before this phase occurs, however, it should be determined whether or not game theory is even appropriate in answering the questions under deliberation. Will a game provide sufficient information or is some other methodology more suitable? Planners should consider other tools that might yield an alternate methodology, as well as the relative value of one tool's result over another. For example, DRDC CORA has several in-house multi-criteria planning tools such as the consensus ranking tool MARCUS [8], the hierarchal ranking tool CapDiM [9] and the Capability Based Planning tool CATCAM [10], to name but a few. However, in this situation Game Theory was chosen for several reasons. First, the requirement to base decisions on high level COAs, as opposed to details at the tactical level precludes the use of some of the other tools (such as CATCAM). Second; Game Theory provides a transparent way of linking outcomes with the participants' inputs (which precludes using tools like MARCUS). Because of these two main reasons, Game Theory became a good candidate to trial in a table-top exercise, which is part of the mandate of the Applied Research Project 13rh under which this exercise fell. In future war games, depending on the goal, Game Theory may or may not be determined to be the appropriate tool. As more table-top exercises are conducted, the list of suitable tools will invariably grow.

74. As for the game itself, or for any other applicable tool, the feasibility of automation should be investigated. With automation, input scores might immediately show local and global game equilibria and strategies, thus allowing for a greater exploration of alternatives.

75. Overall, the application of Game Theory to this case is considered a success. Bearing in mind the uncertainty and the lack of information surrounding the issue, the table-top exercise is thought to have produced reasonable, high-level results, whereas a more detailed approach would not have had great validity. That is, this study in question involves a period in time in the future (10 years) where it is next to impossible to guarantee any of the proposed variables (other state actors, environmental climate, security environment, resources and technologies); consequently, to model "what if's" at

a tactical level (say by considering specific state actors, particular geographic locations, specific military assets, tactics and procedures) would yield unverifiable results and mislead readers in regards to the credibility of the results. By remaining at a very high level and trying to maintain general trends only, these results should provide the Air Force with a *general* sense of the degree of effort that might be required in the Arctic in coming years.

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This study considers alternative scenarios for the Canadian Arctic's future. The best and worst scenarios from environmental, economic and political standpoints, as viewed by Canadian Forces Aerospace Warfare Centre personnel, are then analyzed using Game Theory. The game consists of three players: the Air Force, the Canadian Government and the Adversary. Possible courses of action are assumed for each of the players, a scoring method is adopted, and the game is executed as a table-top exercise. This yields points of equilibrium from which the range of actions that the Air Force might have to take in the defence of Canada's Arctic are determined. This range of actions should provide the Air Force with a general sense of the degree of effort that might be required in the Arctic in coming years.

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