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# North American Aerospace Defense Command (NORAD) Burden Sharing

Ross Fetterly  
Ross Fetterly Consulting

Binyam Solomon  
DRDC – Centre for Operational Research and Analysis

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## Abstract

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We utilize insights from the economic theory of military alliances to quantify the burden sharing in North American Aerospace Defense Command (NORAD). Using various burden sharing measures and peer groups (North Atlantic Treaty Organization [NATO] and Arctic Council), we show that Canada receives substantially more benefits for every dollar in defence expenditures. In addition, our assessment of Royal Canadian Air Force (RCAF) business plan and current defence posture show that there are considerable strategic, institutional, and operational constraints facing the fulfilment of *Strong, Secure, Engaged* (Defence Policy) and possible NORAD modernization. Improving these institutional issues, along with fulfilling the commitments outlined in the Defence Policy, will go a long way to assuaging the burden sharing debate.

## Significance to Defence and Security

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In this Scientific Report we provide a quantifiable assessment of the NORAD burden sharing situation through the application of established economic theories and empirical methods. In addition to proving the first ever quantifiable assessment of NORAD's burden sharing, the report also provides an assessment of the current RCAF posture and the associated implications to NORAD modernization. Some policy recommendations also follow.

## Résumé

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Grâce à nos connaissances de la théorie économique des alliances militaires, nous pouvons quantifier le partage des charges du Commandement de la défense aérospatiale de l'Amérique du Nord (NORAD). À l'aide de diverses mesures de partage des et de groupes homologues (Organisation du Traité de l'Atlantique Nord [OTAN] et Conseil de l'Arctique), nous démontrons que le Canada tire considérablement plus de bénéfices pour chaque dollar investi dans la défense. De plus, notre évaluation du plan opérationnel de l'Aviation royale canadienne (ARC) et de sa position de défense actuelle indique que d'importantes contraintes d'ordre stratégique, institutionnel et opérationnel nuisent à l'application de la politique de défense *Protection, Sécurité, Engagement* et à la modernisation éventuelle du NORAD. L'amélioration de ces questions institutionnelles, ainsi que le respect des engagements énoncés dans la politique de défense contribueront grandement à apaiser le débat sur le partage des charges.

## Importance pour la défense et la sécurité

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Nous avons appliqué des théories économiques établies, ainsi que des méthodes empiriques pour présenter l'évaluation quantifiable de la situation du partage des charges de NORAD contenue dans le présent rapport scientifique. En plus de présenter la toute première évaluation quantifiable du partage des charges de NORAD, le rapport fournit une évaluation de la position actuelle de l'ARC et des répercussions découlant de la modernisation de NORAD. Nous formulons également quelques recommandations de politiques.

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# 1 Introduction

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In late 2020, the Director Research and Development: Defend North America, tasked the Defence Economics Team to undertake a multi-phase research project on the North American Aerospace Defense Command (NORAD) burden sharing and related issues. This Scientific Report is the first in the series, and quantifies the burden sharing calculus using economic theory of alliances and defence resource management concepts. Subsequent studies are expected to broaden the analytical approach as well as expanding the disciplines to include political science, international affairs and related fields. In addition, future projects are also expected to support qualitative and quantitative research with emphasis on the economic effects of various NORAD technologies on local economies and industries.

## 1.1 Background

On February 23rd, during a virtual meeting, Prime Minister Justin Trudeau and the United States (U.S.) President Joe Biden committed to the modernization of NORAD. At that meeting both agreed to “expand cooperation on continental defence and in the Arctic, including the need to modernize NORAD, and discussed their Foreign Affairs and National Defence ministers and secretaries of State and Defense meeting at the earliest opportunity.”<sup>1</sup> While both China and Russia have actively been developing a new generation of long-range capabilities to target North America, both North American partners have been slow to prioritize upgrading NORAD to confront the next generation of offensive threats from both countries (O’Shaughnessy, 2020).

Viewed from a bi-national perspective, there are three primary aspects to consider. First, despite the convention established by having a formal bi-lateral NORAD agreement, it is more importantly a material commitment to common goals, and a visible demonstration of Canadian burden sharing. Second, the backbone of NORAD is the North Warning System (NWS). This bi-national early-warning radar system for the atmospheric air defence of North America consists of 47 radar sites that span the Arctic from Labrador to the Alaska border (Regehr, 2018). The NWS is insufficient to handle the tracking of a number of threats due to the reliance on technology from the 1980s. Finally, the agreement provides Canada with a forum to discuss the broader dimensions of strategic continental defence.

The bi-national NORAD alliance between the much larger U.S. and its smaller neighbour Canada, in terms of economy and population, is an asymmetrical alliance. In alliances of that nature, the smaller country lacks the incentive to share the burden with its neighbour due to the dominance of the larger power (Morrow, 1991). Due to the increasing threats to North America, prioritizing continental defence due to the increasing security threat from China and Russia may induce greater collaboration and investment.

Prioritization implies some quantifiable understanding of the burden sharing status. While there are significant academic discussions on the nature of U.S.-Canada defence relations, we have yet to find an

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<sup>1</sup> Statement from the Office of the Prime Minister of Canada <https://pm.gc.ca/en/news/readouts/2021/01/22/prime-minister-justin-trudeau-speaks-president-united-states-america-joe>, (accessed March 10, 2021).

empirical or quantitative assessment of this unique relationship.<sup>2</sup> We address this gap in the literature by utilizing the economics of alliances framework and defence management concepts.

Specifically, we exploit the burden sharing empirics developed for the analysis of the North Atlantic Treaty Organization (NATO) to quantify the NORAD bi-lateral military arrangement. We also assess the defence management challenges facing the Royal Canadian Air Force (RCAF) in this new era of domestically and continentally focused defence posture.

Using various burden sharing measures and peer groups (NATO and Arctic Council) we show that Canada receives substantially more benefits for every dollar in defence expenditures. We also employ defence management concepts to highlight some existing institutional, strategic, and operational challenges facing the RCAF and its implications to NORAD. We suggest that fulfilling the commitments outlined in *Strong, Secure, and Engaged* (SSE), (DND, 2017) will go a long way to assuaging the burden sharing debate.

The rest of the Report is structured as follows: In the next section we present a brief overview of the military alliance literature and the burden sharing assessment. Section 3 presents the burden sharing analysis while Section 4 outlines some key concepts of defence management with implications to NORAD modernization. The section also summarizes the RCAF resource management challenges and Section 5 concludes.

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<sup>2</sup> For strategic and political science perspective on NORAD see Charron and Fergusson (2020), Fergusson (2010) Jockel and Sokolsky (2015) for example.

## 2 Brief Introduction to the Economics Literature of Alliances

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### 2.1 Theory

We briefly present the economic theory of alliances and its application to the burden sharing analysis below. Sandler and Hartley (2001) provide an authoritative review of the literature. Kim and Sandler (2020) provide a recent assessment of the NATO's burden sharing situation. We adopt the empirical strategy of this latter study in our assessment of NORAD burden sharing.

In economics parlance, defence is characterized as a public good. This is often contrasted with private goods that are purchased in the marketplace where the buyer pays a price that matches her willingness to pay and the marginal cost of the supplier, under competitive provisions. The key insight about a private good is that the purchase is voluntary, and the price matches the purchaser's value of the marginal benefit from consuming the good. The provision is optimal since, at the margin, benefits equal costs.

The provision of national defence, however, may not be optimal since citizens do not willingly reveal their willingness to pay. The unwillingness stems from the key properties of publicness. The first property is non-excludability where a provider of a public good cannot keep a citizen (or a business) from receiving the good's benefits. National defence provided by the Canadian Armed Forces (CAF), for example, cannot be withheld from citizens in a city or province.

The second property is non-rivalness, a situation where the use or consumption of the good does not reduce the consumption opportunities of other citizens from the same unit of the good (Sandler, 2002). A military capability that is deployed to protect one person in a geographic area likely protects others without diminishing (perceptibly) its deterrence effect. These two properties of publicness conceal the true willingness to pay and provide little incentive to citizens to contribute to a collective resource. Consequently, the shared resource must be subsidized in some other way, or it will not be created.

In a seminal article, Olson and Zeckhauser (1966) applied the concepts of pure public goods to military alliances. Specifically, using NATO and its doctrine of mutual assured destruction (MAD), the authors showed that the US nuclear deterrent protected additional allies without diminishing the protection available to existing allies (non-rival). Furthermore, once nuclear deterrence is provided it is available to all allies (non-excludable, Olson and Zeckhauser, 1966).

In a concise mathematical form, the pure public good model of an alliance assumes that each ally allocates national income  $I$  between consumption goods (often normalized to a standard value across an exchange  $y$ , and a public defence good  $Q$ ).<sup>3</sup> The ally's utility (representing the nation's population) is:

$$U^i = U^i(y^i, Q, T) \quad (1)$$

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<sup>3</sup> Sandler and Hartley (2001). A simple two goods utility maximization is provided in Annex A to illustrate the derivation.

The superscript refers to the ally and T is a threat proxy. Also note that,

$$Q = \sum_{i=1}^n q^i \quad (2)$$

Q is the sum of all allies' defence allocation. The two publicness properties discussed earlier are reflected in Equation (2) where alliance-wide defence is the sum of the alliance defence activities and a unit of one ally's defence equally enhances an alliance wide defence. This perfect substitutability results in free riding: an ally relies on the defence provision of others and enjoy the alliance wide benefits (Sandler and Hartley [2001:873]). The budget constraint of an ally is:

$$I^i = y^i + pq^i \quad (3)$$

Recall that  $I$  is income (often proxied by gross domestic product [GDP] in the empirical literature) and the price of the defence good is  $p$ . The consumption good price is set to 1 as per the definition discussed above. The strategic interaction between allies is a Nash equilibrium allocation through the maximization of utility subject to the budget constraint and the best response level for defence in the other allies. The aggregate alliance defence minus the  $i^{\text{th}}$  ally equals:

$$\tilde{Q}^i = \sum_{j \neq i} q^j$$

The constrained maximization problem is:

$$\max_{y^i, q^i} = \{U^i(y^i, q^i + \tilde{Q}^{i*}, T) \mid I^i = y^i + pq^i\} \quad (4)$$

The resulting first order condition from allocating the private good ( $y$ ) and defence ( $q$ ) for each ally Equation (5) is:

$$MRS_{Q,y}^i = p \quad (5)$$

The marginal rate of substitution (MRS) between defence and the private good is essentially the marginal willingness to pay for defence for every ally  $i$ . There are some key assumptions and results from the pure public goods model with implications to our understanding of burden sharing. These are:

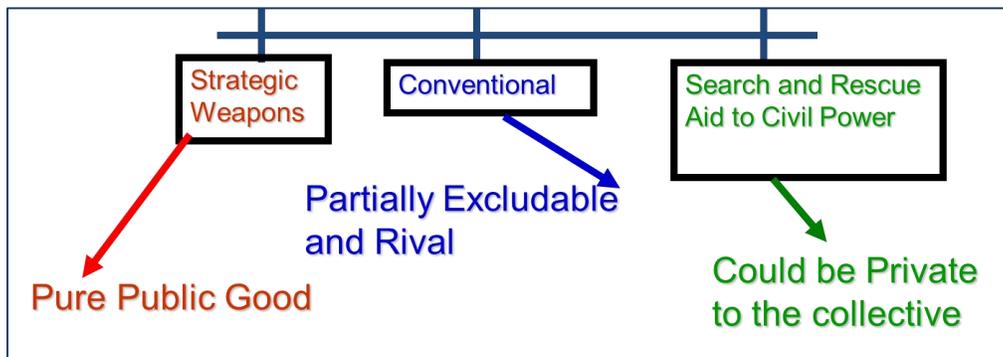
1. Equation (5) implies that the price of defence is the same in the alliance thus there is no comparative advantage in the production of defence.
2. Sub-optimality is prevalent because each ally ignores the marginal benefit it provides to its allies or

$$\sum_{j \neq i} MRS_{Q,y}^j$$

- a. Thus, as the number of allies increases, the extent of the suboptimality worsens.
3. Larger and richer members of an alliance will tend to bear a disproportionately larger share of the defence burden than smaller and poorer ones (the “exploitation hypothesis”) as defence is positively related to income.
4. Free riding implies incentive to contribute is weak and the match between benefits received from defence and costs (burden) are smaller.
5. The game structure is assumed to be simultaneous non-cooperative Nash.
6. The relationship between individual contributions and the overall level of the public good is assumed to be additive and perfectly substitutable.

The relaxation of any of the assumptions lead to outcomes in military alliances that are less pernicious. For example, NATO’s doctrine of MAD of the 1950s and 1960s provided a public good that increased the disproportionate sharing of defence burdens, while the subsequent “flexible response” doctrine attenuated the problem. Essentially, Flexible Response doctrine required nations to rely on a full spectrum of forces, both conventional and strategic (nuclear). Conventional forces provide not only protection and limit damages if deterrence fails, but also other country-specific benefits such as national search and rescue and aid to civil authority capabilities. Thus, the more country-specific benefits of defence spending that accrue to a nation, the more likely it will fund such spending and free-riding is less prevalent (Figure 1).

As shown in Figure 1, defence may produce multiple products with varying degrees of publicness (Sandler and Hartley, 2001). Nuclear arsenals produce non-excludable and non-rival benefits to both the nation that provides it and to the alliance while conventional armaments may be partially rival and excludable due to force thinning (not enough assets to allocate both at home and abroad in unlimited fashion). Some defence assets may only be used for domestic purposes which completely exclude other alliance members. This theoretical model, known as the Joint Products Model, provides more nuanced predictions that not only includes the prediction of the pure public framework but also includes scenarios where free ridership and other suboptimalities are reduced or eliminated.<sup>4</sup>



*Figure 1: Public goods spectrum and joint products model.*

<sup>4</sup> The more defence produces country-specific benefits the more the incentive to contribute to an alliance since substitution is not possible.

The joint-products framework is essentially the relaxation of the assumption (4) above. The theory predicts smaller defence spending burden asymmetries, and that the matching between benefits and burdens will be relatively stronger. Similarly, as noted in Sandler (2004) different game forms (assumption (5) above) can lead to scenarios of both optimal and sub-optimal provision of the public good in question. The leader-follower game (sequential) is one example of the former.

There is a third property of public goods which relates to the overall production or aggregation technology of the good in question (assumption (6)). The original analysis of military alliances by Olson and Zeckhauser (1966) assumed the perfect substitutability of individual contributions leading to the sub-optimal provision of the aggregated public good. Hirshleifer (1983) provides one possible aggregation technology, “weakest link” and its behavioural impacts if everyone is identical in terms of tastes and income.

Specifically, the smallest contribution level determines the overall provision (weakest link) since everyone desires the same level of provision and will match one another’s contributions to the collective good. While this report focuses on the burden sharing empirics, NORAD’s burden sharing can also be explored by examining the theoretical bounds of relaxing both the game structure and various aggregation technologies. This is a worthwhile extension and possible avenue for future research.<sup>5</sup>

## 2.2 Empirics

Olson and Zeckhauser (1966) use an ability to pay measure as a gauge for disproportionality. This disproportionality of defence burdens is typically tested non-parametrically by checking the rank correlation between the allies’ defence burdens and their GDP.<sup>6</sup> Since larger countries tend to shoulder the largest burden in a pure public good setting, a significant relationship between GDP and burden is a signal of exploitation of the large by the small members.

As summarized in Sandler and Hartley (2001) and more recently by Kim and Sandler (2020), all previous studies have found a significant positive rank correlation for the MAD era (1950–66). Given the MAD doctrine’s heavy emphasis on deterrence, a pure public good, these results are consistent with the theoretical predictions. By 1967 NATO’s doctrine changed to flexible response, a strategy of measured response to the Warsaw Pact aggression. Specifically, if the Warsaw pact initiated a small conventional force incursion, NATO will respond with similar conventional countermeasures (Kim and Sandler, 2020).

The doctrine effectively made allies’ defence efforts complementary to one another (Murdoch and Sandler, 1984) as predicted by the joint product model. At the same time, empirical studies that examined NATO since the introduction of this new doctrine failed to show the exploitation of the rich by the poorer alliance members after 1967. To empirically validate the joint product model and to understand the state of burden sharing in NATO post 1967, empirical models utilized measures of defence burdens and benefits. Sandler and Forbes (1980) utilized an “among-ally burden” by relating an ally’s share of NATO’s total spending ( $ME_i/NATO\ ME$ )<sup>7</sup> to its derived benefits from being defended.

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<sup>5</sup> Agier (2020), in an unpublished work, uses aggregation technology to discuss NORAD’s bilateral defence.

<sup>6</sup> Typically, the Spearman rank correlation coefficient ( $\rho$ ) and the Kendall rank correlation coefficient (Kendall tau  $\tau$ ) are often employed to test hypotheses.

<sup>7</sup> For example, Canada’s military expenditures ( $ME_i$ ) divided by the total military expenditures of NATO members ( $NATO\ ME$ ).

Most empirical studies supported the joint product model's prediction that burdens, and benefits are more aligned after the flexible response era (Sandler and Hartley, 2001). The results also held up into the 1990s (except in 1985 with the Regan build-up) and 2000s (Sandler and Shimizu, 2014). However, with the shift in NATO's doctrine to crisis response in the late 1990s, some weaker evidence of the exploitation hypothesis began to emerge (Sandler and Shimizu, 2014). The need for force projection assets and operational engagement out of area implied reliance on the larger NATO member states. The most recent work on NATO burden sharing has uncovered stronger evidence of the exploitation of the richer and larger NATO allies starting in 2010 (Kim and Sandler, 2020).

Hartley (2020) and Kim and Sandler (2020) outline some of the key changes in NATO doctrine, missions and threats that explain the changing burden sharing calculus. First, the out of area missions provide purely public benefits to allies in the form of global stability, increased foreign direct investment opportunities and trade. Second, Russia has emerged as a territorial threat reflected in the annexation of Crimea (February–March 2014) and the invasion of east Ukraine.

Third, proactive actions to weaken networks of Islamic fundamentalist terrorists provide classic non-excludable and non-rival benefits to NATO allies. Fourth, other threats in the form of an emerging superpower China and nuclear capable North Korea require a re-orientation of NATO's defence posture. Finally, "some allies' addiction to the peace dividends of the 1990s places unfair defense burdens on NATO allies responding to new defense challenges" (Kim and Sandler, 2020:404).

The disproportionate burden sharing in NATO evidenced in recent studies (Kim and Sandler, 2020) portend a similar conclusion for the bi-lateral defence arrangement of NORAD. In addition, the changing nature of the threat landscape facing NATO also affects NORAD. Ambitious NORAD modernization of the early warning systems have yet to be fully articulated in Canadian defence planning. In order to empirically ascertain the burden sharing in NORAD we employ similar analytical strategies to those outlined in this section. We acknowledge that there are some practical challenges in employing some of the concepts of burden sharing discussed here. In the next section below, we highlight some of these challenges and the implications to our NORAD burden sharing analysis.

### **2.2.1 Burden-Benefit Measures**

While there are no precise concepts and measures of burdens and benefits, the economics literature is comfortable using military expenditures as a percentage of GDP (within-ally burden) and the proportion of own military expenditures to that of the alliance (among-ally burden). Khanna and Sandler (1997) use alternate burden measures such as peacekeeping spending and foreign assistance, but these do not seem to affect the results. In fact, they note that:

"Peacekeeping spending is minuscule as compared with defense spending. Doing more than one's fair share of peacekeeping cannot do much to offset an under-contribution to defense" (Khanna and Sandler, 1997:116).

More recently Sandler and Murdoch (2000), Sandler and Shimizu (2014) and Sandler and Kim (2020) broaden the burden proxy to include overseas aid and UN assessed contributions to peacekeeping along with military expenditures. The addition of these measures, while providing completeness, do not affect the results obtained by using the traditional burden measure.

On the benefit side, the Sandler and Forbes (1980) strategy of using GDP, population and exposed border is rather common in the literature. The essential argument is that a nation spends on defence (and joins an alliance) to protect its industrial base (GDP), people (population) and territory (exposed borders). However, as Rowlands (2015) notes Canada's extensive coastline makes it the largest free rider in the alliance.

As Khanna and Sandler (1996) acknowledged, "a myriad weighting schemes conceivably could be employed" but the lack of knowledge of the ally's utility function (in regard to the three benefits proxies) constrains one to use a simple average (Khanna and Sandler, 1996:125). Apart from the search for the "optimal" weights for the benefit measures, a constant concern for member states of NATO is the appropriateness of any burden or benefit measures.

Solomon (2004, 2005) and Sandler (2005) debate the weighting scheme and the implication of adding or removing the exposed border proxy. Recently, Kim and Sandler (2020) add a fourth variable, terrorism against targeted country's interests. Specifically, the measure is based on the ally's portion of attacks on its soil (venue) or its portion of attacks on its interests. These two indices are then averaged over the four measures to get a single indicator for each ally (Kim and Sandler, 2020).

We summarize some of the key takeaways from the preceding discussion of burden-benefit measures.

1. Defence as a share of GDP is an input measure and does not reflect outcomes or outputs in the form of security achieved.
2. The assumption that the marginal cost of producing defence is the same across an alliance is not valid since some countries have comparative advantage in producing defence capabilities and defence industries are decreasing cost industries (Hartley, 2020).
3. The exposed border proxy cast nations with large coastlines (Canada) as gross free riders and may be an outlier in the assessment of burden sharing.
4. Studies have broadened the burden measure to include peacekeeping contribution and foreign aid as part of an overall security measure and these did not alter the results significantly.

Given the difficulty in obtaining or developing an output measure of defence, the best strategy is to utilize as many measures as possible and observe whether the results remain consistent. Ironically, the exposed border measure which tends to unfairly impact Canada in burden sharing measures may need to be included in the NORAD assessment. NORAD is primarily a territorial surveillance and defence agreement. The expanded maritime role implies the responsibility of covering the large Canadian coastline. In the next section we examine the burden sharing analysis with and without the coastline variable.

### 3 Burden Sharing Analysis

#### 3.1 NATO

Canada tends to define its security within the context of its multi-lateral and bi-lateral security arrangements (Sokolsky and Middlemiss, 1989). Thus, we begin our analysis with an update of the NATO burden sharing for the last five years. As highlighted in Kim and Sandler (2020) NATO is experiencing disproportionate burden sharing for the first time since the end of the MAD era in 1966. This is mainly due to the changing security threats and member states' under contribution to the collective. Since the same threats also affect the North American theatre, the NATO analysis is instructive.

We utilize the standard datasets as in the extant literature such as military expenditures and defence burden (military expenditure as a share of GDP) from Stockholm International Peace Research Institute (SIPRI, 2020); GDP, population, and price indices from the World Economic Indicators (World Bank, 2021) and exposed borders, proxied by coastlines and land borders with non-NATO countries from the World Fact Book (CIA, 2021).

*Table 1: NATO military burden and ranking 2015–2019.*

	Burden					Burden Rank				
	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019
Albania	1.16	1.10	1.11	1.17	1.27	15	22	22	23	22
Belgium	0.92	0.91	0.90	0.91	0.93	25	26	27	27	27
Bulgaria	1.26	1.26	1.24	1.48	3.22	13	15	17	14	2
Canada	1.15	1.16	1.35	1.33	1.28	16	17	16	17	20
Croatia	1.78	1.62	1.67	1.59	1.67	9	10	11	13	15
Czech Republic	0.95	1.00	0.97	1.11	1.19	23	25	26	25	25
Denmark	1.11	1.15	1.15	1.29	1.32	20	18	21	18	19
Estonia	2.01	2.07	2.01	1.97	2.12	4	3	4	7	5
France	1.87	1.92	1.91	1.85	1.86	5	7	5	9	11
Greece	2.45	2.54	2.52	2.64	2.57	2	2	2	2	4
Germany	1.10	1.15	1.16	1.18	1.28	21	19	19	22	21
Hungary	0.92	1.02	1.05	1.15	1.22	26	23	24	24	24
Italy	1.21	1.34	1.36	1.34	1.35	14	14	14	16	17
Latvia	1.05	1.47	1.59	2.08	2.03	22	12	13	4	7
Lithuania	1.14	1.48	1.72	1.98	2.03	17	11	9	6	8
Luxembourg	0.48	0.44	0.58	0.57	0.62	27	27	28	28	28
Montenegro			1.36	1.43	1.64			15	15	16
Netherlands	1.13	1.16	1.16	1.22	1.34	18	16	20	21	18
Norway	1.51	1.63	1.62	1.63	1.68	10	9	12	12	14
Poland	2.14	1.94	1.90	2.06	2.02	3	6	6	5	9
Portugal	1.79	2.00	1.68	1.86	1.94	8	5	10	8	10
Romania	1.45	1.40	1.72	1.82	2.04	11	13	8	10	6
Spain	1.27	1.14	1.23	1.26	1.24	12	20	18	19	23
Slovenia	0.93	1.01	0.98	0.98	1.05	24	24	25	26	26
Slovak Republic	1.12	1.12	1.10	1.22	1.76	19	21	23	20	12
Turkey	1.82	2.06	2.07	2.55	2.72	7	4	3	3	3
United States	3.48	3.42	3.31	3.32	3.41	1	1	1	1	1
United Kingdom	1.86	1.81	1.77	1.77	1.74	6	8	7	11	13
<b>Average</b>	<b>1.45</b>	<b>1.49</b>	<b>1.51</b>	<b>1.60</b>	<b>1.73</b>					

We convert GDP and military expenditures (ME) data into constant 2018 US dollars using the GDP deflator of each member country. Table 1 presents the data on defence burdens (ME/GDP) and the associated ranking for NATO member countries from 2015–2019. We choose the period as it coincides with the period after the Wales declaration where member states pledged to reverse the decline in defence spending and commit to increase burdens to 2%.<sup>8</sup>

The NATO average over the five years increased from about 1.45% to 1.73% (Table 1). While most of the members are below the 2% guideline, the overall average is moving in the right direction. Canada remains below the target and the NATO average. Interestingly, we see notable movements in the rankings. Specifically, in the last two years, smaller NATO allies such as Bulgaria, Latvia and Slovak Republic have seen significant increases in the ranking while the richer and larger members such as France and the U.K. exhibit declines (Table 1).

It should be noted that SIPRI (2020) highlighted the fact that Bulgaria’s defence spending increased substantially in 2019 because of the full payment for combat aircraft from the U.S. The last year of data from SIPRI may be updated as well since most NATO countries report planned as opposed to actual spending for recent years due to varying reporting dates (fiscal years). However, the significant changes in ranking suggest a possible reversal of the exploitation hypothesis noted by Kim and Sandler (2020).

In Table 2 we present the Spearman rank correlation test between burdens (ME/GDP) and income (GDP). Specifically, we test the null hypothesis that there is no rank correlation between ME/GDP and GDP. A rejection implies support of the explanation in which the rich shoulder a disproportionate share of the burden. We also include a partial rank correlation test that controls for per capita income (GDP/population).

**Table 2:** Spearman rank correlations between defence burden (ME/GDP) and GDP.

Year	Burden: GDP ( $\rho$ )	P. Value	Burden: GDP/Per Capita ( $\rho$ )	P. Value
2013	0.327	0.097	0.412	0.037
2014	0.349	0.075	0.444	0.023
2015	0.316	0.109	0.460	0.018
2016	0.230	0.247	0.362	0.069
2017	0.250	0.200	0.445	0.020
2018	0.105	0.595	0.343	0.080
2019	0.025	0.901	0.331	0.092

Note: Burden: GDP per Capita is a Partial rank correlation coefficient with GDP/population held constant.

While we are unable to reject the null hypothesis (5% level) for the sample period (2013–17), the partial rank correlation holding per capita income constant shows evidence of exploitation for the period 2013–2015 and 2017. This result is somewhat consistent with Kim and Sandler (2020). Unlike Kim and Sandler (2020) exploitation is not evident for the last two years of the sample period. The preliminary data for

<sup>8</sup> [https://www.nato.int/cps/en/natohq/official\\_texts\\_112964.htm](https://www.nato.int/cps/en/natohq/official_texts_112964.htm), (accessed March 5, 2021).

2018 and 2019 shows substantial movement in the ranking of the smaller allies. This foretells fairer burden sharing.

We now turn to the among-ally burden measure to test the joint product model. The model predicts that defence provides multiple outputs with varying degrees of publicness. As such, defence burdens and benefits match if there are sufficient excludable benefits. In Table 3 we present the relative defence burdens and benefits (average of relative shares of GDP, population and exposed borders). Over the five-year period after the Wales declaration, we note the following:

1. Over the last five years the US shouldered 74% of the NATO burden but received 32% of the benefits. Canada, on the other hand, received 23% of the benefits for 2% of the relative contribution.<sup>9</sup>
2. While the large coastline disadvantages Canada, European allies also enjoy large benefits where they accounted for 24% of the relative NATO burden but received 45% of the alliance's benefits.
3. During the period 2015–2019, The U.S. is the only country where burdens exceeded benefits.

For a more robust assessment of the burden-benefit concordance, the extant literature often employs a nonparametric Wilcoxon signed rank test. The test assigns ranks based on the absolute value of the differences between the two measures for each ally in a given year. Specifically, we calculate the z-test statistic using the sum of positive differences. The null hypothesis is that there is a concordance between allies' average benefit shares and their defence burdens.

Table 4 presents the Wilcoxon rank correlation results. At the  $p = 0.01$  level, we reject the null hypothesis of concordance for all the years in the sample. This result strongly suggests the inequality of the burden sharing in NATO and the rise of large pure public benefits from NATO's activities in out of area operations and proactive counter-terrorism stance. Again, the results are consistent with the latest study on NATO burden sharing and stand in stark contrast to earlier studies covering the post-Cold-War period (such as Sandler and Murdoch, 2000; Sandler and Shimizu, 2014). It is also important to revisit the study again in a few years to ascertain if the recent changes in burden ranking and increases in military spending are permanent. If the unprecedented deficit financing of the recent pandemic is an indication, there may be a serious of downward revisions in planned defence spending. Some of this aspect is discussed within the context of NORAD in Section 4.

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<sup>9</sup> This gross burden-benefit mismatch has remained consistent over the last two decades for Canada.

*Table 3: Defence burdens and average of the benefits for NATO 2015–19.*

	Y2015		Y2016		Y2017		Y2018		Y2019	
Country	Defense burden	Benefit share								
Albania	0.02	0.20	0.02	0.20	0.02	0.18	0.02	0.18	0.02	0.18
Belgium	0.38	0.77	0.37	0.77	0.37	0.77	0.37	0.76	0.37	0.76
Bulgaria	0.08	0.40	0.09	0.40	0.09	0.40	0.10	0.39	0.22	0.39
Canada	2.09	22.57	2.11	22.56	2.51	22.55	2.43	22.55	2.28	22.56
Croatia	0.11	0.90	0.10	0.90	0.11	0.89	0.10	0.89	0.11	0.89
Czech Republic	0.24	0.64	0.25	0.64	0.26	0.64	0.29	0.64	0.30	0.64
Denmark	0.41	1.24	0.43	1.24	0.44	1.24	0.49	1.24	0.49	1.24
Estonia	0.04	0.47	0.05	0.47	0.05	0.47	0.05	0.47	0.05	0.47
France	3.99	4.76	4.09	4.74	4.15	4.73	3.95	4.71	3.82	4.69
Greece	0.42	1.89	0.43	1.89	0.43	1.88	0.44	1.88	0.42	1.88
Germany	3.31	5.87	3.49	5.89	3.60	5.88	3.57	5.85	3.72	5.81
Hungary	0.14	0.55	0.16	0.55	0.17	0.55	0.19	0.55	0.20	0.55
Italy	1.95	4.44	2.17	4.41	2.23	4.38	2.13	4.35	2.05	4.31
Latvia	0.03	0.19	0.04	0.19	0.04	0.19	0.06	0.19	0.05	0.19
Lithuania	0.04	0.24	0.06	0.23	0.07	0.23	0.08	0.23	0.08	0.23
Luxembourg	0.02	0.07	0.02	0.07	0.03	0.07	0.03	0.07	0.03	0.07
Montenegro					0.01	0.10	0.01	0.10	0.01	0.10
Netherlands	0.77	1.24	0.80	1.24	0.82	1.25	0.85	1.25	0.90	1.25
Norway	0.70	3.29	0.76	3.29	0.77	3.28	0.76	3.28	0.78	3.28
Poland	1.24	2.03	1.15	2.02	1.17	2.03	1.29	2.03	1.25	2.04
Portugal	0.32	0.70	0.36	0.70	0.31	0.70	0.34	0.70	0.34	0.70

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	Y2015		Y2016		Y2017		Y2018		Y2019	
Country	Defense burden	Benefit share								
Romania	0.33	1.11	0.34	1.11	0.44	1.11	0.47	1.11	0.51	1.11
Spain	1.34	3.07	1.22	3.08	1.35	3.07	1.37	3.07	1.31	3.08
Slovenia	0.04	0.14	0.04	0.14	0.04	0.14	0.04	0.14	0.04	0.14
Slovak Republic	0.09	0.27	0.09	0.27	0.09	0.27	0.10	0.27	0.14	0.27
Turkey	1.38	4.41	1.60	4.45	1.71	4.51	2.10	4.54	2.16	4.56
United States	74.92	32.32	74.25	32.31	73.27	32.27	73.03	32.36	73.26	32.42
United Kingdom	5.60	6.23	5.51	6.24	5.46	6.22	5.34	6.19	5.09	6.19

Note: Benefits include a simple average of relative GDP, exposed borders and population.

*Table 4: Wilcoxon signed rank correlations of ME/NATO ME and average benefit shares.*

Year	Positive Rank Sum
2013	27 ***
2014	27 ***
2015	27 ***
2016	27 ***
2017	28 ***
2018	28 ***
2019	28 ***

\*\*\* significant  $p = 0.01$ .

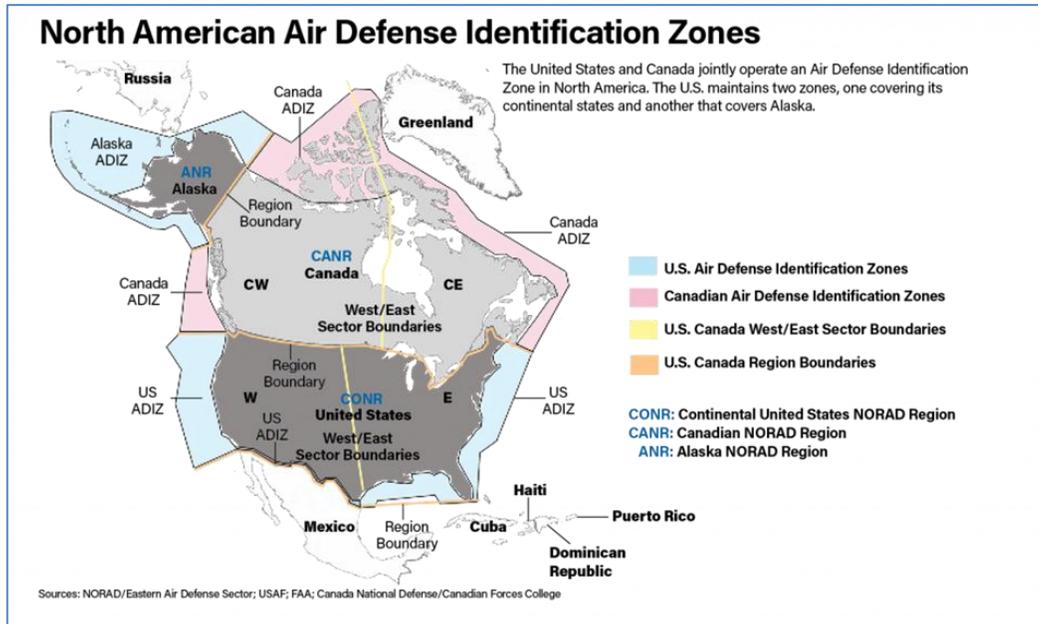
### 3.2 NORAD

NORAD is a bi-national (U.S. and Canada) command responsible for aerospace warning and control for North America. The geographical coverage includes the airspace of Canada and the U.S. (NORAD, 2021).<sup>10</sup> The maritime domain is also part of the NORAD responsibility since 2006. This implies the awareness and understanding of the activities conducted in U.S. and Canadian maritime approaches, maritime areas, and internal waterways.<sup>11</sup>

The NORAD air defence identification zones (ADIZ) are illustrated in Figure 2. The map identifies both the Canadian air defence zones, as well as the division between east and west boundaries. The ADIZ of North America covers the airspace surrounding both countries to provide the space for the identification, location, and control of civil aircraft over the territory.

<sup>10</sup> <https://www.norad.mil/Newsroom/Fact-Sheets/Article-View/Article/578770/north-american-aerospace-defense-command/>, (accessed March 12, 2021).

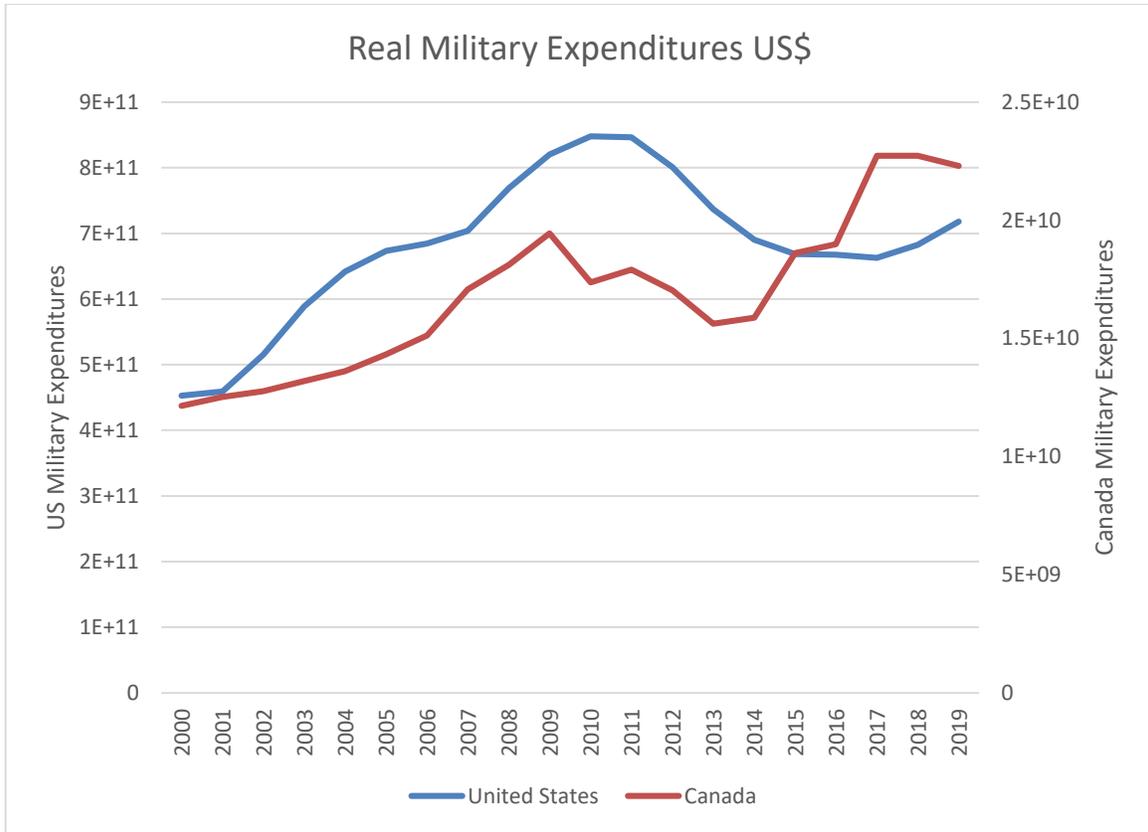
<sup>11</sup> Agreement Between the Government of the United States of America and the Government of Canada on the North American Aerospace Defence Command. Article I, Para I, and Article III. 28 April 2006. <https://www.treaty-accord.gc.ca/text-texte.aspx?lcid=1033&id=105060&t=637537459662909620>, (accessed March 12, 2021).



**Figure 2:** NORAD air defence identification zones Sherman (2021).  
<https://www.airforcemag.com/article/forging-a-shield-for-the-homeland/>.

While warning and control systems are deployed in both the U.S. and Canada, the cost sharing does not seem to follow any fairness or operational criteria. Jockel (2007) points out the original Distant Early Warning Line (DEW Line) operated from 1957–1993 and was entirely funded by the U.S. The replacement known as the NWS, operational since 1993, is funded on a 60/40 U.S./Canada cost sharing.<sup>12</sup> Interestingly, Canada housed about 73% of the long-range radars and 92% of the short-range radars. Similarly, the expanded NORAD role established in 2006 is looking for the modernization of the NWS to address emerging threats from Russia, North Korea and possibly China. The cost sharing formula is not established but the 60/40 split is anticipated to continue.

<sup>12</sup> <https://www.treaty-accord.gc.ca/text-texte.aspx?id=101003>, see paragraph 12, (accessed March 16, 2021).



**Figure 3:** Trend in real military expenditures U.S.-Canada.

Due to the unavailability of public NORAD spending figures for both the U.S. and Canada and the fact that the warning and control of North American aerospace and maritime approaches constitutes the fundamental aspect of both countries’ defence posture, we examine the overall military expenditures. We begin by tracing the trend in real (inflation adjusted) military expenditures between the two nations since the 2000s (Figure 3). We notice that both nations increased military spending in concert after the 9/11 event and then it declined during the financial crisis and Afghanistan withdrawal. We also observe increases in the later years of the 2010s. The degree and timing of the changes are different, but we see general concordance in trends

We next examine the burden sharing using the burden-benefit concordance. As discussed in the NATO section of the empirical study, we use the relative measure of burden ( $ME_i / \sum ME$  NORAD) and the average share of income (GDP), population and exposed borders. The inclusion of the exposed border variable is important in the NORAD perspective even if it penalizes Canada due to its large coastline (Solomon, 2004; 2005).<sup>13</sup> The 2006 NORAD agreement includes the maritime approaches of North America and constitutes the largest coastline of any nation.

As shown in Table 5, the U.S. shoulders about 97.6% of the North American defence burden but receives about 64% of the benefits. Meanwhile Canada contributes about 2% of the burden and enjoys 36% of the

<sup>13</sup> We do not conduct a Wilcoxon test as the sample sizes are too small (N = 2 and N = 5 for Arctic Council).

benefits. For completeness we remove the exposed border variable and assess the burden-benefit concordance. While the US now enjoys 91% of the benefits for 97.6% of the cost, Canada now receives only 9% of the benefits. However, Canada’s burden-benefit ratio is still 1:3.5.

*Table 5: Burden-benefit concordance U.S. and Canada.*

Year	Relative Burden		Avg. Share	
	Canada	USA	Canada	USA
2000	2.61	97.39	35.51	64.49
2001	2.66	97.34	35.52	64.48
2002	2.42	97.58	35.56	64.44
2003	2.19	97.81	35.58	64.42
2004	2.08	97.92	35.59	64.41
2005	2.08	97.92	35.62	64.38
2006	2.16	97.84	35.65	64.35
2007	2.37	97.63	35.76	64.24
2008	2.30	97.70	35.79	64.21
2009	2.32	97.68	35.79	64.21
2010	2.01	97.99	35.81	64.19
2011	2.07	97.93	35.85	64.15
2012	2.08	97.92	35.85	64.15
2013	2.08	97.92	35.88	64.12
2014	2.25	97.75	35.89	64.11
2015	2.71	97.29	35.84	64.16
2016	2.76	97.24	35.84	64.16
2017	3.32	96.68	35.87	64.13
2018	3.22	96.78	35.88	64.12
2019	3.01	96.99	35.90	64.10
Average	2.43	97.57	35.75	64.25
Average (less Borders)			8.75	91.25

While excluding the border gives the U.S. a more or less equal burden-benefit ratio, the new geostrategic reality requires less pre-emptive engagement out of area and a more nuanced protection of the homeland. This North American focus implies more surveillance and control of all domains of the continent. As such, the disproportionate concordance may become an irritant to the long-standing Canada-U.S. defence relationship.

Notwithstanding the new emerging threats, there may also be new economic competition among nations in the polar region. The establishment of the Arctic Council, while originally an environmental monitoring and protection forum of the arctic region, it now also serves to gain recognition of the Arctic States’ sovereignty, sovereign rights, and jurisdiction in the Arctic.<sup>14</sup> The eight countries with sovereignty over the lands within the Arctic Circle constitute the members of the council: Canada, Denmark, Finland,

<sup>14</sup> We acknowledge the anonymous referee’s comment that UNCLOS and the law of the sea are the forum and legal precedents when discussing sovereignty rights and jurisdictional issues related to the arctic.

Iceland, Norway, Russia, Sweden, and the U.S. (China is an Arctic Council observer and self-described “Near-Arctic State” [State Council, 2018]).

Again, to provide another perspective on the burden sharing calculus of NORAD, we situate Canada within the Arctic Council countries. Specifically, we exclude the U.S. and Russia (dominant military powers) and Iceland (no military expenditures) and observe the burden-benefit concordance between Canada, Denmark, Finland, Norway, and Sweden. We recognize that these are not part of a military alliance nor have established a military alliance. The purpose of this exercise is to illustrate potential future geo-strategic alignments given the importance of the polar region for resource extraction and international travel. In addition, if Canada is serious about its northern region both for the protection of its indigenous populous and economic survival, then a comparison to some of its competitors/allies is warranted.

We apply the same relative measure of benefits and burdens and present the results for the period 2000–2019 in Table 6. Compared to the selected Arctic states Canada is indeed larger and contributes roughly 47% of the defence spending. However, it also receives 64% of the benefit. It is also the only country that generates more benefits for a dollar in defence spending. The calculus changes a bit when we remove the exposed border proxy. Here the benefit-burden concordance is lower for Canada, which receives 54% for its 47% contribution. Finland receives an equal concordance in this scenario.

The preceding is to our knowledge the first attempt at quantifying the burden sharing status between the U.S. and Canada. As noted in the survey articles by Hartley (2020) and Rowlands (2015), some nations may have comparative advantage in producing military capabilities which may lead to lower defence budget compared to others that are less efficient. Similarly, the burden measures are input based which do not reveal anything useful about a nation’s true capabilities. However, we observe a consistent story about the disproportionate burden sharing between the U.S. and Canada despite utilizing different combinations of the available measures and peer comparators.

We also note that the assessment of the burden sharing calculus does not point to the “appropriate” level of defence spending for Canada to better reflect the burden-benefit concordance. Matching the benefit ratio would be a significant, if not, prohibitive funding request. For example, increasing Canada’s defence budget to 2% of GDP (almost doubling current spending) will not be enough (given the 1:3.5 ratio estimated earlier).

*Table 6: Burden-benefit concordance select Arctic nations.*

Year	Canada		Denmark		Finland		Norway		Sweden	
	Burden	Benefit	Burden	Benefit	Burden	Benefit	Burden	Benefit	Burden	Benefit
2000	39.67	62.61	13.61	8.54	6.21	5.88	18.14	11.40	22.37	11.56
2001	40.54	62.66	14.29	8.50	5.83	5.89	18.33	11.42	21.02	11.53
2002	39.47	62.88	13.50	8.40	5.71	5.86	21.66	11.37	19.66	11.49
2003	40.16	63.12	12.98	8.30	7.19	5.83	20.43	11.29	19.26	11.46
2004	41.45	63.17	12.94	8.24	7.59	5.82	19.89	11.29	18.14	11.47
2005	43.89	63.40	12.27	8.17	7.83	5.79	17.57	11.23	18.44	11.41
2006	45.28	63.48	13.08	8.15	7.84	5.78	16.12	11.16	17.67	11.43
2007	48.30	63.81	11.84	7.99	6.97	5.77	15.86	11.08	17.03	11.35
2008	50.63	63.93	12.07	7.94	7.50	5.76	14.81	11.09	15.00	11.28
2009	51.89	64.07	10.91	7.87	7.38	5.64	16.17	11.18	13.65	11.23
2010	48.63	64.10	12.08	7.81	7.63	5.63	16.14	11.08	15.53	11.38
2011	50.17	64.21	11.51	7.75	7.82	5.62	15.62	11.02	14.88	11.40
2012	48.62	64.35	12.09	7.70	8.05	5.55	15.78	11.10	15.46	11.30
2013	46.85	64.50	11.64	7.66	8.43	5.48	16.90	11.09	16.18	11.27
2014	46.95	64.60	10.93	7.62	7.84	5.41	17.69	11.07	16.59	11.29
2015	50.67	64.43	9.96	7.64	7.25	5.38	17.01	11.09	15.11	11.46
2016	50.00	64.35	10.27	7.70	7.06	5.38	17.95	11.07	14.73	11.50
2017	54.29	64.42	9.49	7.68	6.30	5.36	16.60	11.04	13.31	11.50
2018	53.13	64.50	10.65	7.67	6.30	5.33	16.52	11.00	13.40	11.50
2019	50.78	64.57	10.88	7.70	6.72	5.29	17.35	10.97	14.27	11.48
<i>Average</i>	<i>47.07</i>	<i>63.86</i>	<i>11.85</i>	<i>7.95</i>	<i>7.17</i>	<i>5.62</i>	<i>17.33</i>	<i>11.15</i>	<i>16.59</i>	<i>11.42</i>
<i>Average*</i>		<i>54.37</i>		<i>10.43</i>		<i>7.80</i>		<i>11.05</i>		<i>16.35</i>

Note: \*Excluding exposed borders.

Nevertheless, maintaining the current trajectory and fulfilling the re-investment in key military assets promised in SSE are the minimum. Unfortunately, as pointed out in Solomon and Penney (2020) the Canadian Department of National Defence (DND) averaged about a 20% slippage in capital expenditures since the late 2000s. This means that the expected SSE investments may not be realized due to procurement challenges and bureaucratic inertia. In the next section we examine some of the organizational and management challenges facing the RCAF and the implications to the NORAD modernization.

## 4 Defence Resources Management

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In the preceding sections, we utilized the economics of alliances framework to provide an empirical or quantitative economic assessment of NORAD. The economics of alliances also provides a more macro aspect of the bi-lateral relationship. This high level (macro) assessment is mainly pragmatic due to the unavailability of public NORAD spending figures for both the U.S. and Canada.

In the absence of such NORAD specific data, we turn to defence management concepts to provide a micro understanding of institutional, operational and tactical factors that may affect NORAD tasks and potential modernization. Specifically, this section examines the RCAF given the traditional aerospace focus of NORAD, the domestic and continental focus of SSE and NORAD modernization goals. The section briefly introduces defence management concepts followed by nuanced discussions on readiness and force generation.

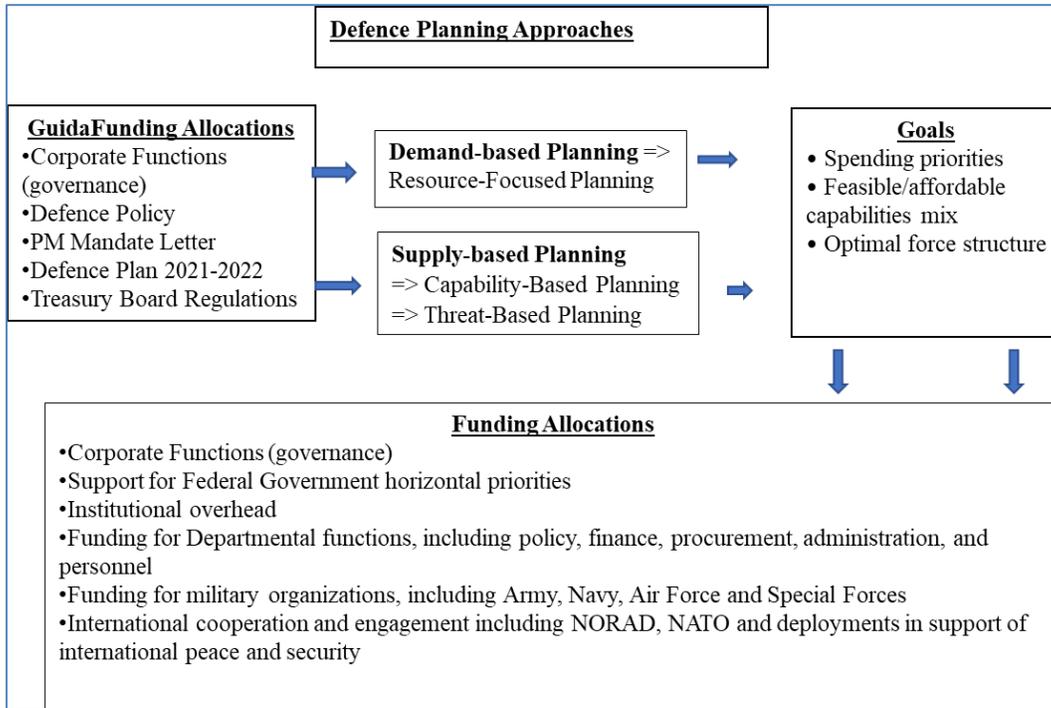
### 4.1 Management Concepts

“The past few years have been a reminder that stability is not the natural state of the international environment, that peace is not self-perpetuating, and that whole regions can descend suddenly into anarchy” (Dobbins et al., 2015:xiv).

The defence planning process transforms resources into military capabilities in accordance with government policy.<sup>15</sup> To accomplish government direction articulated through defence policy, resources are put through a deliberate business-process mechanism. The desired objective is to establish and execute a rational method of documenting organizational priorities and objectives, while communicating them internally and addressing any perceived constraints. While the defence policy remains the framework under which defence is resourced, annual defence allocations can vary for several reasons. Figure 4 outlines the process of translating federal guidance into annual funding allocations (Mazarr et al., 2019:Figure 2.1).

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<sup>15</sup> Resources in this context includes funding and directions from the central government which may include strict limits on the number of personnel or quantities of equipment.



*Figure 4: Process of translating guidance into allocations.*

## 4.2 Military Readiness

“The strategic threat to the homeland has entered a new era. Key adversaries Russia and China have deployed and continue to advance a range of capabilities to hold the homeland at risk with nuclear, conventional, and cyberspace weapons, believing it to be an effective means of offsetting Western military advantages and limiting our options in a crisis.” (O’Shaughnessy, 2020).

The above quotation from the American NORAD Commander in 2020 conveys a sense of danger and vulnerability of the North American continent in a presentation to the US Senate Armed Forces Committee, while highlighting the sensitivity of multiple diverse threats to the U.S. While the previous section highlighted the importance of transforming resources into capabilities, this section addresses the issue of readiness and its implications for NORAD modernization.

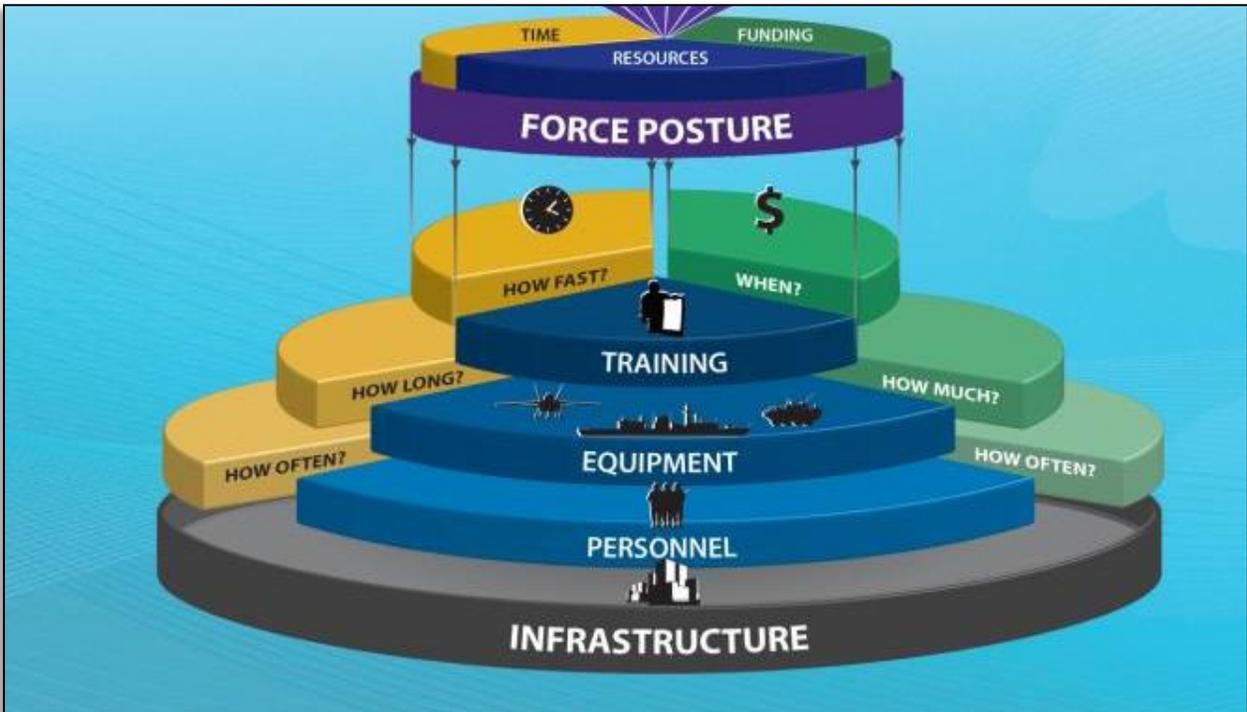
Discussions on burden sharing in an alliance, or in a bi-national defensive organization like NORAD, need to place readiness as a primary institutional priority. Of primary importance is the ability to measure readiness. In essence, if you can express readiness in quantifiable numbers, then this illustrates your understanding and application of readiness concepts. In contrast, the inability to quantify readiness, demonstrates a lack of knowledge about the subject. Viewed from that perspective, debates regarding the defence budget are “in many respects, a debate over readiness.” (Harrison, 2014). There are three fundamental readiness questions with implications to RCAF:

1. Readiness for What?—The type of conflicts NORAD must be able to fight.

2. Readiness for When?—The time interval required to respond to threats to North America.
3. Readiness of What?—An understanding of which parts of the American and Canadian militaries need to be ready and at what state of readiness.

In NORAD modernization, structural readiness is an essential component of that process. This type of readiness is necessarily outward looking towards having the right infrastructure, equipment, and weapon systems, as well as the trained crews and personnel to operate them successfully when engaging the opponent. Of particular importance to NORAD, the amount of time it takes to develop structural readiness takes considerably more time than for operational readiness. Furthermore, technical modernization of infrastructure or weapon systems are increasing the amount of time needed to operationalize new or modernized units. Consequently, a certain level of structural readiness can be viewed as a prerequisite to operational readiness in the operational environment of North American aerospace defence.

The recent US House Armed Services Committee report entitled Future of Defense Task Force Report concluded that “policy makers and the Pentagon must navigate a major course correction in how we invest in national security.” (U.S., 2020). The 2018 US National Defense Strategy had earlier stated that the U.S. was “emerging from a period of strategic atrophy, aware that our competitive military advantage has been eroding.” (DoD, 2018) More recently, two senior serving American General Officers called for a “broader framework for readiness to better integrate elements of current availability, effects across combatant commands, future availability and readiness, and modernization efforts.” (Brown and Berger, 2021).



*Figure 5: Force posture and readiness trade-offs.*

The shifting global security environment is changing the historical dynamics of Canadian and American defence resource allocation. Readiness and capital equipment procurement are increasing in importance, as well as levels of trained and effective RCAF aircrew and maintenance personnel.

As highlighted in Figure 5, four key variables determine the readiness and force structure of the RCAF in relation to the NORAD modernization. The first deals with governance and structure of the RCAF. The second deals with RCAF personnel while the third consists RCAF operations and maintenance of equipment. The fourth factor is institutional force generation and project management.

### 4.3 RCAF as the Franchise Monopolist<sup>16</sup> for Air Resources

As the sole provider of air assets to the CAF, RCAF's capacity is constrained significantly during crisis or conflict. There are no substitutes for Canadian or American military aircraft fleets. The emerging continental focus will only complicate matters further.

Both NORAD and USNORTHCOM released a combined strategy in March 2021 that aligns with objectives identified in the Interim US National Security Strategic Guidance, American National Defense Strategy, and Canada's Strong Secure Engaged (SSE) defence policy titled *NORAD and USNORTHCOM Strategy Executive Summary*. The strategic environment is described in that document as follows:

“For decades, our nations enjoyed the benefits of dominant military capabilities in all domains, and we relied on our geography to serve as a barrier to keep our nations beyond the reach of most conventional threats. Our ability to project power forward along with our technological overmatch has allowed us to fight forward and focus our energy on conducting operations overseas. However, our competitors have analyzed our ability to operate overseas and have invested in capabilities such as ballistic missiles, cruise missiles, hypersonic weapons, small, unmanned aircraft systems, artificial intelligence, cyber capabilities, and delivery platforms to offset our strengths while exploiting our perceived weaknesses.” (DoD, 2021).

The North American Aerospace Defence Command focused on the defence of our continent can be viewed as an increasingly important element of the core Canadian collective security triad that also includes the North American Treaty Organization (NATO) and the United Nations (UN). Indeed, SSE preferences strong at home and secure in North America as the first two of three priorities, with a commitment to work with the U.S. to make sure NORAD is updated to counter either current or future challenges, as well as a “strong commitment” (DND, 2017:16) to renew the NORAD agreement. In 2018, the summary of the U.S. National Defense Strategy of the U.S., emphasized that the American “homeland is no longer a sanctuary” (DoD, 2018). While the Canadian defence policy also emphasized the return of deterrence to the “centre of defence thinking” (DND, 2017:50), with NORAD renewal the focus of our report. Finally, the U.S. Constitution lists “providing for the common defense” as one of the primary responsibilities of Congress (U.S., 1787).

This continental focus along with the potential economic significance of the polar region will impose significant challenges to this traditional triad focus. If economic theory is any guide, the excludable

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<sup>16</sup> A franchised monopoly in this context implies the granting of an exclusive license or legislation to a company or armed forces component to shelter it from competition. In the CAF, all air assets are managed and owned by RCAF and air components are leased or provided to the Navy and Army.

benefits of continental defence outweigh global commitments to UN and RCAF's support to global engagements.

Throughout history, the differentiator in military operations could previously be measured in terms of scale and potency, today it is more about agility and the ability to create an appropriate military effect. The RCAF, as with other military organizations, can be considered as a multifaceted system, which converts resource inputs into operationally ready forces. Because this transformation “involves a set of interactions among the inputs, many of which may be nonlinear, the output can at times appear random or unexpected.” (Harrison, 2014). Complexity is amplified by the dynamic nature of the system, the relentless advances in technology, incessantly shifting international strategic environment, the need to adapt operational concepts to that environment, as well as more abstract factors such as leadership, which when combined ends up transforming the military over time.

Force generation of RCAF military personnel is an ongoing institutional challenge, as with the other services. As a force generator, the RCAF is focused on ensuring that its personnel are well-led and well-trained and well-equipped for a variety of different operations. The next section will discuss force generation with a NORAD focus.

#### **4.4 Force Generation-RCAF**

Air Force readiness is the responsibility of the RCAF Commander. Indeed, it is the “raison d'être of the RCAF.” (DND, 2017B). RCAF readiness is a secondary outcome of a range of different variables, including recruitment of RCAF personnel, initial pilot and other aircrew training, fighter aircraft training and skills maintenance training, maintenance of aircraft fleets, and institutional yearly flying rate (YFR) allocations. Within these variables, the RCAF must balance readiness, adaptability, and the overriding need for military effectiveness against budgetary constraints; as such, an emphasis on efficiency in operation and resource allocation is needed.

Force generation in the RCAF includes both aircrew and ground crew. Specifically, the RCAF fiscal year (FY) 2021–22 Business Plan (RCAF, 2021) identifies shortfalls in funding for aircraft maintenance technicians, and a range of unfunded training issues. For example, the Fighter Force Maintenance Renewal Program (FFMRP), has a funding shortfall in the RCAF FY 2021–22 Business Plan of \$3.2M in the next Fiscal, increasing to \$10M in FY 2022–23.<sup>17</sup> FFMRP is a RCAF project created in response the challenges the Fighter Force is facing in meeting its current mandate along with meeting the augmented personnel requirements for the absorption of the Australian Interim Fighter Capability Project aircraft as well as the transition to the Future Fighter Capability Project. Military pilot training in Canada capacity shortfalls in the RCAF 2021–22 Business Plan requests \$7.1M in FY2021–22 with increases in the next two Fiscal Years for the Euro-NATO Joint Jet Pilot Training (ENJJPT)—Fighter Pilot Production in the U.S. to maintain pilot Newly Wing Grad production and facilitates in extending the life of the CT-155 Hawk to the end of NATO Flying Training in Canada (NFTC) contract.<sup>18</sup> Changes in the aircraft maintenance training continuum by resequencing the training, decreases training time to Trained

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<sup>17</sup> Annex A, Appendices 1 CAD, Resource Request Detail—Fighter Force Maintenance Renewal Program (FFMRP).

<sup>18</sup> Annex A, Appendices 32 CAD, Resource Request Detail—Euro-NATO Joint Jet Pilot Training (ENJJPT)—Fighter Pilot Production.

Effective strength, increases operational capacity, and parity in movement and benefits between occupations at an incremental cost of \$2.8M in FY 2021–22.<sup>19</sup>

The RCAF Commander has identified the need for senior RCAF officers deploying into air task force command without the necessary training in air and space power expertise. This lack of capability is affecting the contributions of deployed RCAF members to the joint operational environment as well as the institutional credibility of the RCAF. Funding an Air and Space Power Commanders Course (ASPCC) at the RCAF Air Warfare Centre in the RCAF Business Plan is requested at an annual cost of \$1.2M.<sup>20</sup> Finally, with NFTC program is being extended to 2027 plus one option year to continue pilot training until Future Aircrew Training (FAcT) Program reaches ready for training, incremental funding for the contract in FY2021–22 starts at \$10.6M in that year and to \$66.9M in FY 22–23.<sup>21</sup> To enable the RCAF to operate optimally in the Future Security Environment, and also to share the burden of a revitalized and modernized NORAD agreement, the capacity of both the department and RCAF needs to increase.

#### **4.4.1 Future Aircrew Training (FAcT) Program**

The mandate of the FAcT Program is to develop and implement a new and cohesive training program that replaces the extant CAF's Pilot, Air Combat Systems Officer, and Airborne Electronic Sensor Operator training systems. Due to contract end-dates for Contracted Flying Training and Support and NFTC, this activity is not discretionary. Continuity and re-orienting training to the future security environment is also necessary to prepare aircrew to work in the future NORAD environment. Funding requested in the FY 21–22 BP for FAcT program for operations and maintenance (O&M), excluding a one-year internal offset of \$6.8M is \$1.9M and salary and wage envelope (SWE) requirements starting on that FY are \$3.1M and increasing by over \$1M a year for the next two years.<sup>22</sup>

### **4.5 Operation and Maintenance of RCAF Equipment**

Closely related to the problem of personnel generation is the utilization of equipment, which serves both the training of personnel and the employment of the trained personnel to operational theatre as required. The RCAF flying rate for a given FY is called the YFR. Figure 6 illustrates the factors that impact on the ability of the RCAF to generate a combined RCAF fleet YFR. In general, it consists of O&M funding for the year, and these are near-term variable costs. These costs are aviation fuel, in-year contracted services, and military base support services. Medium term costs are fixed and consist of national procurement type services, including major aircraft maintenance cycles and mid-life upgrades. Long-term costs are derived from government policy and they are centred on force structure, such as the quantity of aircraft in different fleets.

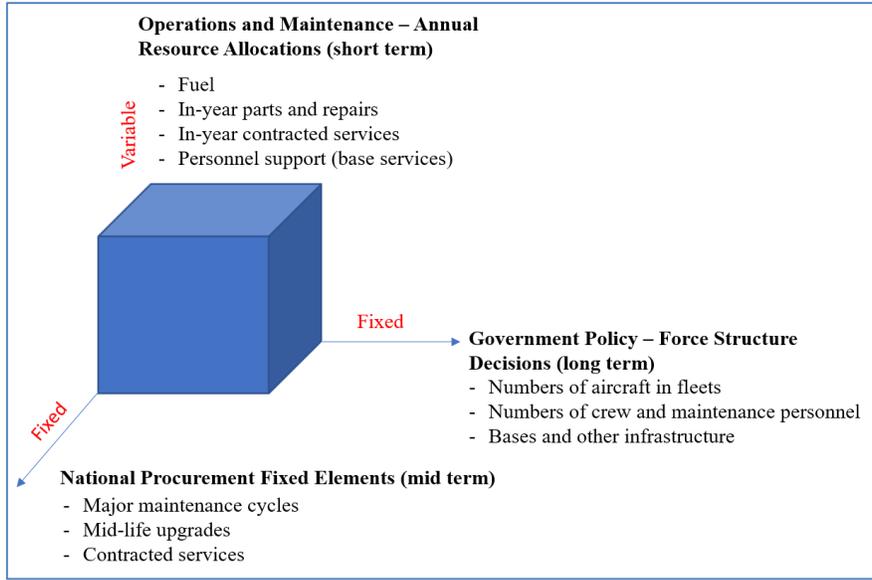
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<sup>19</sup> Annex A, Appendix 35—2 CAD, Resource Request Detail—Aircraft Maintenance Tech Training Re-Sequence.

<sup>20</sup> Annex A, Appendix 41—RCAF AWC, Resource Request Detail—Contracted support for delivery of Air and Space Power Commanders Course (ASPCC).

<sup>21</sup> Annex A, Appendices DAST Appendix 54—RCAF DAST, Resource Request Detail—NFTC Extension (NFTC-X).

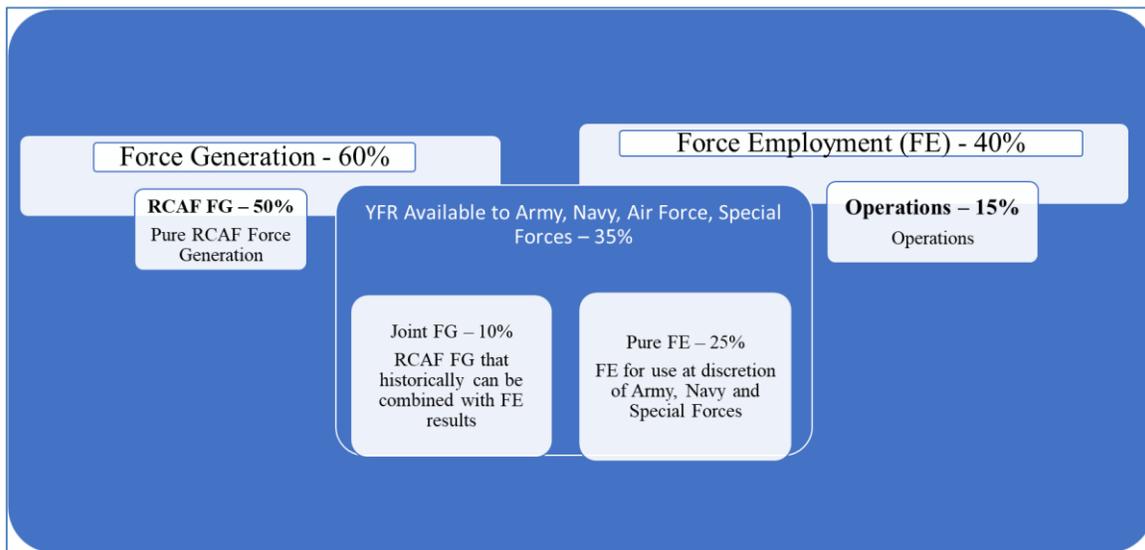
<sup>22</sup> Annex A, Appendices Air Staff, Appendix 3, Resource Request Detail—Future Aircrew Training (FAcT) Program FY 21–22 request of \$5M.



*Figure 6: Factors affecting annual YFR availability.*

The annual RCAF YFR plan is developed through the Total Air Resource Management process, and generally follows the apportionment in Figure 7. Although this is a planning guideline, the actual apportionment can vary on an annual basis, based on training requirements or operational demands.

The YFR is tracked closely by fleet and consists of two primary elements: force generation (FG) and force employment (FE). This relationship is illustrated in Figure 7, and flying hours in FG and FE can vary between fiscal years. Force generation flying hours supports the future force. These flying hours are used to train and develop pilots and aircrew to attain and maintain qualifications, as well as enhance their qualifications. Force employment utilizes the current force.



*Figure 7: Simplified yearly flying rate (YFR allotment) (approximate distribution).*

#### 4.5.1 Implication of an Aging CF-18 Aircraft Fleet and Crowding out of Procurement Capacity

The Auditor General of Canada (OAG) in a 2018 report, estimated that within the procurement timeline at that time, the department would have to extend the retirement date to 2032, to enable the transition to the replacement fighter fleet. The OAG noted with concern that the CF-18 “will be about 50 years old and will have fallen an additional 15 years behind combat technology if no upgrades are made.” (OAG, 2018).

The OAG also concluded that the fighter force could not meet the “government’s new operational requirement, which is to have enough aircraft ready each day to meet the highest NORAD alert level and Canada’s NATO commitment at the same time.” (OAG, 2018). The reasons given were a shortage of maintenance technicians and the aging aircraft. The inability of the collective political parties in Parliament to replace the CF-18 fleet by 2020 has significant implications for NORAD modernization.<sup>23</sup>

First, when discussions regarding modernization of NORAD capabilities are just beyond the horizon, it brings the reliability of Canada in question, on a capability that directly affects the security of North America. Second, for Canada, NORAD modernization increases the size of the bow wave<sup>24</sup> of projects by the department now having to add to the existing capital program (including the large and expensive next generation fighter capability acquisition project), further exacerbating the capacity of government to direct expenditures to other defence capital equipment projects, as well as a variety of personnel recruitment or capacity issues. Also known as the procurement death spiral, where “year-over-year under execution” (White, 2019) of capital equipment procurement projects and funding allocated by the government accumulates. This cumulative bow wave of RCAF capital equipment projects will create either a crowding out of projects in the Army, Navy, or department, or limit the number of RCAF capital equipment projects that can be undertaken simultaneously. The 2019 update to the 2018 DND Investment Plan already advised that over the next 10 years the government will be increasing defence spending on projects “by almost \$33 billion, an increase of more than 70%.” (DND, 2019). This bow wave of defence projects will also spread across other Federal government departments, including Public Services and Procurement Canada, the Treasury Board Secretariat, and Department of Finance.

#### 4.6 Departmental Force Generation and Project Management

NORAD modernization in the middle of major re-equipment of the CAF implies the need to quickly adapt not only RCAF resources but institutional organizations responsible for government procurement. While the RCAF focuses on capability development, RCAF specific training and operations; Assistant Deputy Minister (ADM) Materiel (Mat) supports the RCAF with capital equipment management of a range of large air force projects and the Vice Chief of the Defence Staff Chiefs of Programme and Force Development organizations provide institutional support and oversight of the RCAF program. We begin the section with an overview of current RCAF major capital equipment projects followed by the implied NORAD modernization.

<sup>23</sup> See Annex B for Past and Current CF-18 deployments for non-NORAD commitments.

<sup>24</sup> The term “bow wave” in defence is a metaphor for result of delayed capital equipment programs, where the expenditure of equipment funds is delayed into the future. The large backlog creates a growing bow wave of needed funds, as well as institutional capacity to address.

#### 4.6.1 Current RCAF Major Capital Equipment Projects

The RCAF and department are currently managing a number of large air force capital equipment acquisition projects listed in Figure 8.<sup>25</sup> These projects for both new or replacement capabilities—from air force systems to new aircraft, are currently requiring a level of operational RCAF officers and DND procurement officers and other specialists. SSE provides Vote 5 (capital budget) funding for numerous RCAF projects. However, projects in the Identification and Options Analysis phases require RCAF Vote 1 (operating budget) funding to progress to Definition. Moving projects forward to meet SSE timelines requires personnel with expertise in Project Approval and Project Management. Consequently, the RCAF transferred \$7M in SWE funds for Project Management Personnel Support (PMPR) for civilian employees required in ADM(Mat), ADM(Information Management) (IM), and ADM(Infrastructure and Environment) (IE).<sup>26</sup>

- The CF-18 Fighter Aircraft Replacement Project.
- Replace the Tanker Transport Capability project—Replace the in-flight refueling, utility transport, and multi-mission aircraft fleets (CC-150 Polaris replacement).
- Operationalize the new Fixed-Wing Search and Rescue Fleet (CC-295 Kingfisher).
- Acquire Space Capabilities to enhance Situational Awareness and Targeting.
- Replace Utility Transport Aircraft (CC-138 Twin Otter replacement).
- Acquire next generation multi-mission aircraft (CP-140 Aurora maritime patrol aircraft replacement).
- Acquire a Medium Altitude and Armed Remotely Piloted Aircraft System.
- Acquire new Aircrew Training Systems.
- Upgrade Air Navigation, Management, and Control Systems.
- Modernize short-range air-to-air missiles (Fighter Aircraft armament).
- Recapitalize or life-extend existing capabilities in advance of the arrival of next generation platforms.
- Sustain domestic search and rescue capability.

*Figure 8: Current investments in RCAF large capital equipment projects.*

A recent audit by Assistant Deputy Minister (Review Services) on the Preliminary Requirement Process for Capital Equipment Projects, focused on the capacity of project teams responsible for the preliminary requirement development process, highlighted the importance of project team capacity. (DND, 2019B). This capacity will be further challenged by the addition of proposed NORAD modernization projects. This will not be incremental change, as the scale and scope of the combined current capital equipment projects already in progress in DND, together with NORAD projects will necessitate change in how these projects are planned, staffed, and managed.

<sup>25</sup> Department of National Defence (2018) Defence Plan 2018–2023—Annex A (DND, Ottawa). [Annex A - Defence Plan 2018-2023 - Canada.ca](#), (accessed March 20, 2021).

<sup>26</sup> Annex A, Appendices Air Staff, Appendix 4, Resource Request Detail—Transfer of RCAF SWE Funds to ADM(Mat), ADM(IM), ADM(IE) personnel using PMPRs to advance RCAF projects.

The RCAF FY 2021–22 Business Plan includes a wide variety of funding requests for initial staff work for capital equipment projects identified in SSE Space activities,<sup>27</sup> that would also support NORAD activities. For example, Multi-Purpose Space Surveillance Satellite research and development. This activity will look forward to Surveillance of Space (S of S) 2's eventual successor, S of S 3, and examine the best way forward/emerging technology, in order to de-risk any capability gap that would exist following the decommissioning of S of S 2 and the deployment of S of S 3.<sup>28</sup> In addition, the DND Deputy Minister agreed with the Canadian Space Agency (CSA), to re-purpose RADARSAT Constellation Mission (RCM) contingency funds for the purposes of concept studies for the next CSA initiative called Earth Observation Service Continuity (EOSC), with initial RCAF funding of \$1M.<sup>29</sup> With space an emerging and increasingly important domain, the Canadian government needs to increase their long term capacity in DND and the RCAF in capabilities within that domain.

Long-term under-expenditure on capital equipment can also drive higher O&M costs through the usage of aging equipment. NORAD modernization with its new and unfunded capital programs will thus compete with the much-delayed replacement of the CF-18 fleet along with the management of a wide range of procurement programs listing in the 2017 Defence Policy. A final note, the air force is generally reliant on foreign manufacturers, with the exception being Canadian membership in the F35 Consortium. In recent years, the Canadian government was able to take advantage of foreign production lines for the CC-130J Hercules, CC-177 Globemaster and CH-147F Chinook aircraft. Future military aircraft production lines may not be available when the Canadian government needs to buy certain fleets or to replace aircraft that were heavily damaged or destroyed.

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<sup>27</sup> Annex A, Appendices Air Staff, Appendix 8, Resource Request Detail—RCAF/DG Air FD/DSR: DSR lacks the staff necessary to address the additional workload generated by SSE identified projects, to grow the space domain. Funding the annual cost for the seven positions is \$780K.

<sup>28</sup> Annex A, Appendices Air Staff, Appendix 8, Resource Request Detail—RCAF/DG Air FD/DSR: Multi-Purpose Space Surveillance Satellite research and development. This activity will look forward to Surveillance of Space 2's, eventual successor (S of S 3), and examine the best way forward/emerging technology, in order to de-risk any capability gap that would exist following the decommissioning of S of S 2 and the deployment of S of S 3. BP request of \$2M. This project would support NORAD activities.

<sup>29</sup> Annex A, Appendices Air Staff, Resource Request Detail—RCAF/DG Air FD/DSR: RCM/EOSC. Transfer of funds to the Canadian Space Agency for a concept studies for the next CSA initiative called Earth Observation Service Continuity (EOSC). Transfer from the RCAF to CSA of \$1M.

## 5 Conclusions and Future Directions

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NORAD was established as a bi-national military organization between Canada and the U.S. in 1958, by formal agreement between both countries. This bi-national organization “institutionalized a means for Canada to contribute to the formation of continental defence and thus helped to legitimize full participation in a fundamentally unequal relationship” (Nossal, 2020:15–16). The joint defence of the North American continent remains a core component, and increasingly important focus of both national governments. The agreement has been renewed on a regular basis, with a maritime component added in 2006 that included a maritime warning mission to NORAD’s already existing missions.

The shifting international strategic environment has brought NORAD back to the forefront of North American security. With the North America under an increasingly greater security threat from Russia and China in 2021, the need to modernize NORAD infrastructure is becoming more apparent. As such the NWS replacement should be accelerated.

Based on the economics of alliance framework we can provide the first ever empirical assessment of the burden sharing status between the U.S. and Canada. Using various burden sharing measures and peer groups (NATO and Arctic Council) we show that Canada receives substantially more benefits for every dollar in defence expenditures. In addition, this disproportionality has persisted throughout much of the 2000s and 2010s.

While the empirics suggest Canadian under investment in defence, increasing funding to match the significant estimated benefits is not realistic. For example, in some estimated cases, Canada must triple its commitment to match the benefits received! The review of the current defence posture also suggests the need for a credible commitment to fulfil what is promised in SSE and expected in the modernization of NORAD.

Specifically, our assessment of RCAF business plan and current defence posture show that there are considerable strategic, institutional, and operational constraints facing the fulfilment of SSE and possible NORAD modernization. We identify the following:

1. Force generation of Canadian military aircrew and maintenance personnel has been an enduring problem to match requirements in response to capacity limitations and attrition.
2. Institutional capacity within the civilian and military branches is limited and is challenged to provide capacity and oversight of project growth expenditures, and further exacerbated by potential management of new NORAD projects.
3. As a franchise monopoly, the RCAF will have limited assets to deploy to international deployment and the more enhanced continental stance. The government must make some choices and trade-offs.
4. As the OAG noted, a shortage of maintenance technicians coupled with and the aging aircraft are making the existing fighter fleet hard to maintain. The inability of the collective political parties in Parliament to replace the CF-18 fleet by 2020 has significant implications for NORAD modernization.

Improving these institutional issues along with fulfilling the commitments outlined in SSE will go a long way to assuaging the burden sharing debate. We also acknowledge that U.S. and Canadian marginal costs of producing defence capabilities are not the same. As such, Canada may have comparative advantage in producing key capabilities that that may be useful for continental defence. The available public data do not allow us to conduct such an analysis. We hope that data availability will allows us to test this hypothesis in the future.

Similarly, it is not possible to estimate military outcomes or outputs and the reliance on input measures such as military expenditures may not reveal Canada's actual contribution to continental defence. However, sustained, and targeted increases are required to address the new domestic focus. In addition, the emerging importance of the polar region adds urgency and real commitment. Given the country specific and excludable benefits of continental and polar defence, economic theory predicts that Canada will be incentivized to increase its defence spending.

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## Annex A Derivation of Pareto Optimal Provision

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Assume a Pareto efficient allocation where consumer 1 is as well off, given consumer 2's utility:

$$\max_{x_1, x_2, Q} u_1(x_1, Q)$$

Subject to:

$$u_2(x_2, Q) = \bar{u}_2$$

$$x_1 + x_2 + c(Q) = w_1 + w_2$$

The budget constraint the sum of endowments or income ( $w_1 + w_2$ ) to be spent on quantities of the private goods ( $x_1$  and  $x_2$ ) and public good  $Q$ . Note that in the non-cooperative Nash version of this optimization problems consumer 1 ignores the contribution of consumer 2 and maximizes own utility subject to own budget constraint.

The constrained optimization is then the Lagrangian:

$$L = u_1(x_1, Q) - \omega[u_2(x_2, Q) - \bar{u}_2] - \mu[x_1 + x_2 + c(Q) - w_1 - w_2]$$

Differentiating with respect to  $x_1$  and  $x_2$  and public good  $Q$ :

$$\begin{aligned} \frac{\partial L}{\partial x_1} &= \frac{\partial u_1(x_1, Q)}{\partial x_1} - \mu = 0 \\ \frac{\partial L}{\partial x_2} &= -\omega \frac{\partial u_2(x_2, Q)}{\partial x_2} - \mu = 0 \\ \frac{\partial L}{\partial Q} &= \frac{\partial u_1(x_1, Q)}{\partial Q} - \omega \frac{\partial u_2(x_2, Q)}{\partial Q} - \mu \frac{\partial c(Q)}{\partial Q} = 0 \end{aligned}$$

Re-arranging and dividing by  $\mu$ :

$$\frac{1}{\mu} \frac{\partial u_1(x_1, Q)}{\partial Q} - \frac{\omega}{\mu} \frac{\partial u_2(x_2, Q)}{\partial Q} = \frac{\partial c(Q)}{\partial Q} \quad (\text{A.1})$$

Solving for the multipliers:

$$\mu = \frac{\frac{\partial u_1(x_1, Q)}{\partial x_1}}{\frac{\mu}{\omega} \frac{\partial u_2(x_2, Q)}{\partial x_2}}$$

And substituting into Equation (A.1):

$$\frac{\partial u_1(x_1, Q)/\partial Q}{\partial u_1(x_1, Q)/\partial x_1} + \frac{\partial u_2(x_2, Q)/\partial Q}{\partial u_2(x_2, Q)/\partial x_2} = \frac{\partial c(Q)}{\partial Q}$$

Implying that:

$MRS_1 + MRS_2 = MC(Q)$  the marginal cost of providing an additional unit of the public good (Q) equals the sum of each consumer's marginal rate of substitution of the private and the public good.

Again, note that the non-cooperative Nash solution excludes the endowments of consumer 2 and the constancy of her utility. The resulting level of the public good excludes  $MRS_2$  similar to the result shown in Equation (5). In an alliance of large membership, the suboptimality adds up faster.

## Annex B Current CF-18 Domestic and International Operations<sup>30</sup>

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- *Operation LIMPID*—RCAF provides aerospace domain awareness in coordination with the Canadian NORAD Region.
- *Operation IGNITION*—NATO regional security support for Iceland. Based on a NATO rotation, a task force including a CF-188 Hornet fighter aircraft detachment of up to six aircraft on a rotational basis may be sent as well as an aircraft support team.

### *Past CF-18 Operations*<sup>31</sup>

- Kuwait—from October 2014 until February 2016, as part of Op IMPACT, Canada's fighter fleet deployed to Kuwait in support of the allied coalition to fight the atrocities of Daesh in Iraq, and also later in Syria. The CF-18s conducted 1378 sorties, resulting in 251 airstrikes.
- Op REASSURANCE (2014) CF-18s patrolled European skies alongside NATO partners, building confidence in Europe's stability and security.
- Operation Mobile (2011)—Air Force Task Force Libeccio (Libya)—946 sorties by CF-18 aircraft and 3,881.7 flying hours. Support for the CF-18 operations included 672.4 CC-130 Hercules tanker hours, 89.5 CC-130J Hercules transport aircraft hours, 1,379.8 CC-150 Polaris tanker hours, and 1,403.1 CP-140 Aurora long-range surveillance aircraft hours.
- Serbia (1999)—Operation Echo18 CF-18s participated in NATO air strikes against Serbian forces, conducting 10 per cent of all strikes, including 558 bombing missions.
- Bosnia and Herzegovina (1997)—Operation Mirador Air patrols in support of NATO peacekeepers.
- Kosovo Campaign (1999) Operation Echo and Kinetic—deployment of 18 CF-18s to Italy.
- Gulf War (1990–91)—Operation Friction deployment of 24 CF-18s to Qatar. This deployment was Canada's first combat engagement since the Korean War.

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<sup>30</sup> DND. 2021. Current Operations List. <https://www.canada.ca/en/department-national-defence/services/operations/military-operations/current-operations/list.html>, (accessed March 29, 2021).

<sup>31</sup> DND. 2021. Recently Completed Missions. <https://www.canada.ca/en/department-national-defence/services/operations/military-operations/recently-completed/operation-mobile.html>, (accessed March 29, 2021).

## List of Symbols/Abbreviations/Acronyms/Initialisms

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ADIZ	air defence identification zone
ADM	Assistant Deputy Minister
ASPC	Air and Space Power Commanders Course
CAF	Canadian Armed Forces
CSA	Canadian Space Agency
DND	Department of National Defence
DRDC	Defence Research and Development Canada
ENJJPT	Euro-NATO Joint Jet Pilot Training
EOSC	Earth Observation Service Continuity
FAcT	Future Aircrew Training Program
FE	force employment
FG	force generation
FY	fiscal year
GDP	gross domestic product
IE	Infrastructure Environment
IM	Information Management
MAD	mutual assured destruction
ME	total military expenditures
MEi	Canada's military expenditures
MRS	marginal rate of substitution
NATO	North Atlantic Treaty Organization
NFTC	NATO Flying Training in Canada
NORAD	North American Aerospace Defense Command
NWS	North Warning System
O&M	operations and maintenance
OAG	Auditor General of Canada
RCAF	Royal Canadian Air Force
RCM	RADARSAT Constellation Mission
SWE	salary and wage envelope
U.S.	United States
YFR	yearly flying rate

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We utilize insights from the economic theory of military alliances to quantify the burden sharing in North American Aerospace Defense Command (NORAD). Using various burden sharing measures and peer groups (North Atlantic Treaty Organization [NATO] and Arctic Council), we show that Canada receives substantially more benefits for every dollar in defence expenditures. In addition, our assessment of Royal Canadian Air Force (RCAF) business plan and current defence posture show that there are considerable strategic, institutional, and operational constraints facing the fulfilment of *Strong, Secure, Engaged* (Defence Policy) and possible NORAD modernization. Improving these institutional issues, along with fulfilling the commitments outlined in the Defence Policy, will go a long way to assuaging the burden sharing debate.

Grâce à nos connaissances de la théorie économique des alliances militaires, nous pouvons quantifier le partage des charges du Commandement de la défense aérospatiale de l'Amérique du Nord (NORAD). À l'aide de diverses mesures de partage des et de groupes homologues (Organisation du Traité de l'Atlantique Nord [OTAN] et Conseil de l'Arctique), nous démontrons que le Canada tire considérablement plus de bénéfices pour chaque dollar investi dans la défense. De plus, notre évaluation du plan opérationnel de l'Aviation royale canadienne (ARC) et de sa position de défense actuelle indique que d'importantes contraintes d'ordre stratégique, institutionnel et opérationnel nuisent à l'application de la politique de défense Protection, Sécurité, Engagement et à la modernisation éventuelle du NORAD. L'amélioration de ces questions institutionnelles, ainsi que le respect des engagements énoncés dans la politique de défense contribueront grandement à apaiser le débat sur le partage des charges.