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A COMPARATIVE ANALYSIS OF MINIMUM RESOURCE REQUIREMENTS FOR SINGLE AND MIXED FLEETS FOR THE NATIONAL FIGHTER PROCUREMENT EVALUATION OF OPTIONS

KEY FINDINGS

- Based on reasonable assumptions, the RCAF can maintain anticipated domestic and international commitments using a single fleet of 65 fighter aircraft and 90 pilots.
- A mixed fighter fleet can provide the same or equivalent capability, but not without significantly more aircraft and pilots.
- Mixed fighter fleets comparable in size to the single fighter fleet will likely result in lower overall capability, at a higher cost.

BACKGROUND

As part of its effort to fulfill and exceed the recommendations in the 2012 Spring Report of the Auditor General of Canada, the Department of National Defence is in the process of evaluating options to sustain a fighter capability for the Canadian Armed Forces (CAF) well into the 21st century (Ref. A). The options under consideration to replace the CF-18 Hornet include four fighter aircraft currently in production or scheduled to be in production (Ref. B). In addition to evaluating these replacement aircraft individually, this analysis considers the possibility of replacing the CF-18 with a mixed fleet consisting of two different types of aircraft. A mixed-fleet solution could prove beneficial if, for example, it reduces the risk of the entire fighter fleet being grounded due to safety of flight or other concerns. However, acquiring two types of aircraft only makes sense if it provides sufficient capability to achieve the level of ambition for the CAF, as outlined in the *Canada First* Defence Strategy (CFDS; Ref. C), and the aircraft can be acquired, manned, and maintained at a reasonable cost over their respective lifetimes. The purpose of this report is to compare aspects of single versus mixed aircraft fleets, in particular those pertaining to fleet size, number of pilots, and anticipated costs.

The idea of a mixed fleet is not new to Canada. The CF-18 acquired through the New Fighter Aircraft Project replaced three aircraft operated by the Royal Canadian Air Force (RCAF): the McDonnell CF-101 Voodoo, the Canadair CF-104 Starfighter, and the Canadair CF-5 Freedom Fighter. Estimating the savings realized by replacing the CF-101, CF-104, and CF-5 with the CF-18 is quite challenging to do in any meaningful way. The number of aircraft was reduced through this process as was the scope of the missions carried out by the fighter force. This means that even if reliable costing data from that era were available, which is not the case, any cost comparisons would be of the "apples to oranges" variety.

Nonetheless, there is ample evidence that minimizing the number of types of aircraft in a fleet does lead to cost savings. For example, the US Navy estimated that by reducing its number of helicopter types from eight to two that it would save $20 billion alone in Sikorsky SH-60 Seahawk life cycle costs (Ref. D). Similarly, the idea of introducing "fleet commonality" in the airline industry is widely believed to be an effective cost-saving measure (e.g., Refs. E and F). In fact, Refs. G and H both show scientific evidence that this belief has merit for the airline industry; fleet commonality has a positive effect on airline profitability.

In addition to these examples, many countries have recently planned multi-role fighter aircraft designs with the specific intent of reducing the number of aircraft fleets. These programs are all designed with cost savings in mind. Amongst others,

- the Saab JAS 39 Gripen was designed to replace the Saab 35 Draken and Saab 37 Viggen in Sweden;
- the Dassault Rafale was designed to replace the SEPECAT Jaguar, the Vought F-8P Crusader, the Dassault Mirage F1 and 2000 series, the Dassault Etendard IVPM, and Dassault-Breguet Super Etendard aircraft operated by the French Air Force; and
- the Lockheed-Martin F-35 Lightning II was designed to replace the General Dynamics F-16 Fighting Falcon and Fairchild Republic A-10 Thunderbolt II in operation by the USAF (F-35A) as well as the McDonnell Douglas F-18 Hornet[1] (A/B/C/D variants) and the McDonnell Douglas AV-8B Harrier II aircraft in operation by the US Marine Corps (F-35B).

Ref. I, despite focusing exclusively on US multi-service fighter programs, provides some evidence that such programs may not always realize the envisioned cost savings.

Despite the existence of a substantial number of programs designed to reduce the number of aircraft fleets, there are still many countries that operate mixed fleets of fighter aircraft by choice. The so-called "high-low" mix of aircraft in which a larger number of smaller, cheaper, and less capable aircraft is paired with a smaller number of larger, more expensive, and more capable aircraft is common amongst larger air forces. The USAF has long employed this model, most notably with the McDonnell Douglas F-15 Eagle and the F-16. The Indian Air Force intends to continue with three tiers of fighter aircraft even after the completion of its Medium Multi-Role Combat Aircraft competition (Ref. J). Australia has recently decided that it will continue to operate its fleet of Super Hornets alongside the F-35 when it comes into service, although this was not the original intent (Ref. K). Given that there are examples on both sides of the argument, it makes sense to examine the circumstances under which such a decision for Canada could be cost effective.

It is important to note that mixed-fleet options are distinct from bridging options. The former are primarily concerned with the acquisition, operation, and support of two new fleets of aircraft to replace the CF-18. The latter center around some form of shorter term solution to ensure there is no gap in fighter capability in the 2020-2025 timeframe. This can be achieved through an upgrade program to extend the life of the CF-18 fleet, with eventual acquisition of replacement aircraft, or the staggered acquisition of two fleets of aircraft, the first arriving before the CF-18 reaches its

[1] The US Navy will replace its remaining F-18 aircraft with the F-35C to fly alongside the F-18E/F Super Hornet, which is manufactured by Boeing after its merger with McDonnell Douglas.

estimated life expectancy and the second coming into service at some later point in time. The costs involved with bridging options make them unsuitable for filling capability gaps in the short term; any short term investment results in disproportionately high costs during the bridging period.[2] When viewed as a longer-term solution, implementing a bridging option is tantamount to operating a mixed fleet due to having two fleets operating together for an extended period of time. These arguments are nearly identical to the ones espoused in Ref. M for Australia's use of the Super Hornet as a bridge to their planned eventual procurement of the F-35 Joint Strike Fighter. This analysis assumes that the Government of Canada will not take on significant additional costs beyond those identified for replacing the CF-18, and so bridging options will not be further considered in this document.

METHOD

The CFDS identifies three roles for the CAF: defending Canada, defending North America, and contributing to international peace and security. The CAF's level of ambition is further defined through six core missions, which could potentially need to be carried out simultaneously. For the fighter force, the Government of Canada's level of ambition centers primarily on its domestic commitments to the North American Aerospace Defense Command (NORAD; Ref. N) and its expeditionary commitments through the North Atlantic Treaty Organization (NATO; Ref. N). For the purposes of this analysis, the most stringent domestic requirements are captured through the NORAD agreement. To assess the demands in an expeditionary context, the CAF commitments to NATO are used.

The adopted approach makes use of the Air Force Structure Analysis (ASTRA) model developed by the Defence Research and Development Canada, Centre for Operational Research and Analysis (Ref. O), and used by the RCAF since 2000 to gain insight on the feasibility of force structures for many of its fleets, including the CF-18. ASTRA calculates the number of aircraft and fighter pilots required to meet specified commitments by considering the complex interplay of many factors which affect aircraft utilization rates. For instance, every mission requires a certain number of aircraft to be flown and a sufficient number of pilots to fly the required sorties. The pilots require training to get and remain proficient, or "combat ready," and so a number of aircraft and instructor pilots are required to lead this training. In addition, because of military posting cycles, a significant portion of the pool of combat-ready pilots is transferred to non-flying positions, increasing the overall amount of training required. Aircraft are also limited in how much flying they can do in any given year and must undergo periodic maintenance. The key to creating a sustainable force structure is to reconcile all the demands on the fleet in terms of flying hours and maintenance with the available supply of aircraft and pilots because of all the inherent dependencies that exist within the supply and demand. However, additional concerns such as technological risks of implementing any of the proposed solutions are beyond the scope of the model and hence this report.

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[2] For example, when Australia decided to purchase 24 Super Hornets to fill a temporary capability gap between the retirement of its F-111C/G Aardvarks and the acquisition of its F-35A, it did so estimating the cost to own and operate the aircraft for ten years to be approximately $6 billion (Ref. L). Australia has since decided to keep its Super Hornets in service for the long term.

The assumptions specified in Annex A are representative of a generic fleet of fighter aircraft capable of fulfilling NORAD and NATO commitments with 65 aircraft, as per the CFDS. The values are not indicative of any specific replacement option, but rather represent generic expectations for fleet performance, particularly at the beginning of the fleet's life, based on current knowledge. Although these values are illustrative of expected future fighter employment, they are nonetheless critical in this analysis as they help establish a benchmark against which mixed fleets can be compared. It is important to note however that lessons drawn from this analysis are valid irrespective of the specific values chosen.

RESULTS – SINGLE FLEET

To begin with, it was assumed that Canada intends to acquire, as signaled in the CFDS, a single fleet of some 65 aircraft with the plan of using it for all missions. Table 1 summarizes the degree to which commitments, both domestic and expeditionary, can be fulfilled. Where possible, both the NORAD and NATO commitments were fulfilled simultaneously. The table also indicates whether force generation[3] activities can continue while concurrently satisfying these commitments. In addition to these results, it was determined that 90 pilots would be required to achieve these levels of capability. Annex A provides more detail on how the resources, aircraft and pilots, are distributed. In Annex A, it is assumed that 20% of the fighter aircraft are undergoing long-term preventive maintenance and that 30% of the remaining aircraft are unserviceable at any given time. Thus, it is not surprising that a fleet of 65 aircraft can be expected to provide a maximum of 36 aircraft for given mission. Ref. P shows that this situation is not unusual; it estimates that 39–56% of a given RCAF fleet's aircraft are mission ready at any given time.

Table 1: Single fleet capability.

NORAD	NATO	Force Generation Capability (FGC)
Max 12	6 sustained	Not affected
Max 24	6 sustained	Suspended
36	Suspended	Suspended

Table 1 shows three results. The first row indicates that with a fleet of 65 jets it is possible to sustain an indefinite rotation of 6 serviceable aircraft for expeditionary missions and scramble 12 serviceable aircraft for domestic missions, without affecting force generation. The second row shows that if the FGC is temporarily shut down, a maximum of 24 serviceable aircraft can be used for NORAD missions without impacting the NATO deployment. The final row indicates that it is possible to scramble 36 serviceable aircraft for NORAD purposes, but expeditionary and force generation activities must all be suspended. Note that while Canada "supports the NATO Response Force and contributes assets when possible" (Ref. Q) there is no hard minimum requirement for the NATO commitment. However, as shown in Ref. O and the flying hour

[3] Force generation is the process of organizing, training, and equipping forces for operations. In the present context, force generation can be thought of as being virtually synonymous with training.

allocations in the last few years' Total Air Resource Management documents, the RCAF anticipates the potential for NATO involvement on an indefinite basis. Since this level of commitment is feasible with a single fleet of 65 aircraft, it is used as the baseline for the purposes of comparison for the mixed fleets introduced in the next section of this report.

RESULTS – MIXED FLEET

To ensure that the comparison between single and mixed fleets is as relevant as possible, the analysis holds fixed as many of the assumptions described above as possible. The intent is to determine how the resource requirements change for a mixed-fleet capability that is comparable to a single fleet capability. Optimized solutions will seek to minimize the resources needed to deliver an equivalent capability. However, one additional constraint needs to be applied to the mixed fleet: no deployment of aircraft, for NORAD or NATO missions, will consist of two aircraft types.[4] From a resourcing perspective, this reduces inefficiencies as well as simplifying operational and logistic considerations.

The first step is to establish the most appropriate way to build and optimize the mixed fleet. It must be assumed that the two aircraft in the mixed fleet consist of a lower capability, lower cost aircraft (Fleet A) and a higher capability, higher cost aircraft (Fleet B). Moreover, Fleet A must be assumed to be inadequate in satisfying part of the domestic or expeditionary commitments. Otherwise there is no optimization required from a capability perspective and the optimal solution mathematically consists of a single fleet of the lower cost aircraft from Fleet A.

Given the nature of the missions outlined in the CFDS, Core Mission 5: Lead and/or conduct a major international operation for an extended period is the mission that introduces the highest potential threat, particularly when dealing with a near-peer adversary, and therefore requires the more sophisticated and capable aircraft to conduct the mission. For this reason, it is assumed that Fleet B will be sufficient in size to address the commitment to NATO. In doing so, it is also assumed that Fleet B possesses sufficient capability to satisfy the NORAD commitment, if used in this role. Fleet A is assumed to be capable of satisfying the NORAD role, but inadequate for some aspects of the NATO role.

The analysis of the mixed fleet structure began by calculating the resources necessary to indefinitely sustain a rotation of six serviceable aircraft for NATO missions. A total of 63 Fleet B aircraft and 71 pilots[5] were needed to fulfill this requirement, which is just short of being capable of providing the 36 aircraft needed for NORAD. At first, these numbers may seem quite high. However, the demands (in flying hours) of all the pilots required to sustain this deployment is what drives the number of aircraft in this case. Given these results, optimizing this mixed fleet means either adding two Fleet B aircraft to increase the total to 65 or enough Fleet A aircraft to generate at least six serviceable jets for NORAD. The first option simply reverts the mixed fleet into a single fleet. The second option requires 19 Fleet A aircraft and an additional 22 pilots, which clearly represents a less cost-effective solution.

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[4] This does not preclude using two types of aircraft to satisfy, say, NORAD commitments. Rather, it means that the two aircraft will operate as separate units rather than operating as a single larger unit when deployed

[5] This number does not include any so-called designated pilots; see the Annex for a discussion of their role and their impact on the force structure.

Another possibility that was investigated was the option of reducing the commitment to NATO of Fleet B in an effort to create a more balanced, and less costly, mixed fleet. In this situation, it was assumed that the NATO rotation would be sustained for a period of one year,[6] on six-month rotations. It was determined that 38 Fleet B aircraft, along with 46 pilots, would be required to fulfill the NATO commitment. Similarly, it was also found that 36 Fleet A aircraft and 47 pilots would be needed to provide sufficient aircraft to satisfy the NORAD commitment. Annex A shows the distribution of the 74 total aircraft and 93 personnel while Table 2 shows the capability provided by this mixed fleet.

Table 2: Mixed fleet capability
(*italics* / **boldface** indicate decreased / increased capability relative to the single fleet).

NORAD	NATO	Force Generation Capability (FGC)
Max 18	*6 × 2 rotations*	Not affected
Max 24	*6 × 2 rotations*	**Suspended (1 FGC)**
36[7]	Suspended	Suspended (both FGCs)

As before, the first row shows the number of aircraft that can be scrambled for the NORAD mission without affecting the NATO mission and the force generation activity for either aircraft type. In this situation, it is possible to provide an additional six aircraft for the NORAD mission compared to the single fleet case. Additionally, this case as well as the one shown in the second row provides less capability to the NATO mission since the deployment cannot be sustained indefinitely. The second row shows that force generation activity needs to be suspended for only one of the two aircraft types in order to provide 24 NORAD aircraft. Therefore, force generation activities are less affected than in the single fleet case. The final row shows that as in the single fleet case both the NATO deployment and all force generation activity needs to be temporarily suspended to satisfy the full NORAD complement of 36 aircraft.

COST CONSIDERATIONS

The previous section showed a mixed fleet of 74 aircraft does not deliver the same capability as a single fleet of 65 aircraft. This section examines known cost considerations in an effort to compare the single and mixed fleets. Despite having a sub-fleet of lower cost aircraft, the loss of economies of scale combined with the cost of duplication may result in a mixed fleet that is more expensive than its single fleet counterpart as was shown in a recent estimate of sustainment costs of future Australian fighter fleets (Ref. R).

[6] The period of one year was chosen for illustrative purposes. Repeating the analysis with deployments of, say, six, eighteen, or twenty-four months is straightforward and will yield similar findings.

[7] While this mixed fleet is capable of generating more than 36 aircraft for a NORAD mission, anything beyond this number is in excess of the current requirement. The figure is nonetheless shown in bold to indicate that the additional aircraft provide increased flexibility when managing the fleet in this situation. This added flexibility could be used in a number of ways, including continuing force generation activity at a reduced rate.

Figure 1 presents a fitting analogy that helps one understand that reducing acquisition costs alone is completely insufficient to ensure mixed fleet costs are comparable to those of a single fleet. The studies at Refs. S and T provide evidence that is consistent with the existence of significant fixed operating, support, and infrastructure costs associated with any aircraft fleet. In the case of a mixed fleet, extra costs result from duplication: infrastructure; aircraft maintenance support equipment; operational and maintenance training; supply lines; project management; engineering support; aircraft certification; test and evaluation; storage and management of spare parts, weapons, and expendables; and electronic warfare and systems reprogramming are just some of the many sources of duplication amongst the two sub-fleets.

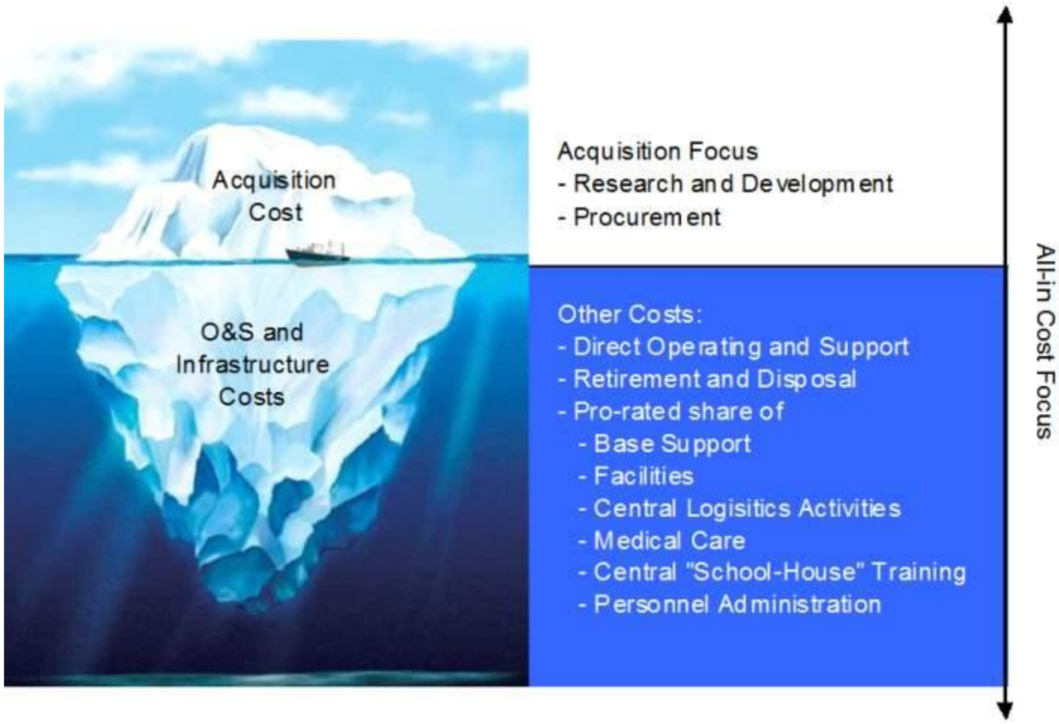

Figure 1: Life cycle cost iceberg (from Ref. U).

As outlined in Annex A, Refs. S and T can be used as the basis for a parametric analysis of mixed-fleet costs. Uncertainty in the parameters is introduced and Monte Carlo simulation[8] is used to approximate the costs of the single and mixed fleets. The goal is not to estimate these costs explicitly, but rather to identify the approximate conditions under which a mixed fleet may cost less than a single fleet. Using this method, it was found that when the acquisition cost of Fleet A aircraft is approximately 50% of the acquisition cost of Fleet B aircraft, it is essentially a break-even proposition that the mixed-fleet will be less expensive than the single fleet.

[8] This technique is used to approximate the likelihood of certain outcomes through the use of multiple trial runs. Uncertainty in the parameters is captured using random variables.

CONCLUSIONS

This report compared a single fleet of aircraft, capable of fulfilling Canada's NATO and NORAD commitments, against a mixed fleet consisting of these higher capability, higher cost aircraft combined with lower capability, lower cost aircraft. The analysis found that a mixed fleet of 38 higher capability aircraft, chosen for their ability to fulfill the most challenging of the NATO missions, and 34 lower capability aircraft, capable of fulfilling Canada's NORAD obligations, could not provide the same capability as the single fleet of 65 higher capability aircraft.

Assessing the viability and affordability of any particular aircraft or mix of aircraft is beyond the scope of this report, and as such this analysis assumes that any fleet size argument pre-supposes the suitability of any chosen option from a capability perspective. This report showed that unless the acquisition cost of the lower cost aircraft is half of the acquisition cost of the higher cost aircraft or less, then there is strong evidence to suggest that the mixed fleet is providing less capability at higher cost. While not definitive, this cost estimate is still indicative of the relative costs required to make a mixed fleet competitive with the single fleet from a cost perspective. If changes to Government of Canada policy were to lessen capability demands on the fighter force, then acquiring, operating, and maintaining a mixed fleet may become feasible without incurring additional cost.

Fundamentally, the decision to purchase a single type of aircraft or two different aircraft will be a function of the aircraft's ability to satisfactorily execute the desired mission set at an acceptable cost. This report showed that if Canada should choose to acquire a mixed fleet of fighter aircraft, then unless the acquisition cost of the lower capability aircraft is half or less that of the higher capability aircraft, the mixed fleet is expected to not only result in reduced overall fleet capability, but to also cost more over its lifetime, relative to a single fleet of the higher capability aircraft.

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ANNEX A: FORCE STRUCTURE ANALYSIS

This annex documents the more technical aspects of the analysis, including the assumptions that were used to derive the conclusions of the report.

CAPABILITY ANALYSIS

The inputs used for the important parameters in the ASTRA model to calculate the capability of the single fleet are provided below. These values were obtained through consultation with subject matter experts, supplemented by the information found at Ref. V, and were deemed representative of a generic fighter fleet, capable of fulfilling both the NORAD and NATO missions as they are currently executed. They are grouped by mission, with those that are common to both NORAD and NATO commitments labeled "Common."

Common:

- Aircraft availability: 80%
- Aircraft serviceability: 70%
- Yearly flying rate per aircraft: 170 hours during low operations tempo / 210 hours during high operations tempo
- Number of squadrons per aircraft type: two, including a Force Generation Capability[9] (FGC) for each aircraft type
- Yearly pilot training requirement: 200 hours (combined live flying and simulator time)
- Simulator usage rate for training: 40%

In addition, a standard posting length, derived from years of recent operational experience, is used throughout. Currently, postings in the fighter community are approximately three years in length.

NORAD:

- Number of aircraft required:[10] up to 36
- Manning rate:[11] 1.5:1

NATO:

- Size of deployment: 6 serviceable aircraft
- Manning rate: 2:1
- Sustainment ratio:[12] 3:1

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[9] For the CF-18, the FGC is currently fulfilled by 410 Tactical Fighter Operational Training Squadron, distinct from the two Tactical Fighter Squadrons at Bagotville and Cold Lake

[10] In order to keep this analysis unclassified, the capability of any fleet in fulfilling NORAD commitments will be addressed in increments of six serviceable aircraft to a maximum of 36, irrespective of actual commitments.

[11] The manning rate in this context is the ratio of pilots to aircraft that are deployed on the given mission. In the case of the NORAD mission, three pilots are deployed for every two aircraft.

[12] A 3:1 sustainment ratio indicates that once deployed on an expeditionary mission, personnel are ineligible for redeployment until another three rotations have cycled through the theatre of operations.

Whether dealing with single or mixed fleets, it is assumed that the fleet hours capture the currency requirements for designated pilots,[13] who occupy positions at Wing Ops, the Air Force Tactical Training Centre (AFTTC), and the Fighter Standards and Evaluation Team (FSET). The planned allocation for these positions for FY13-14 has an additional 21 such pilots (Ref. V), although only 19 of these positions are currently manned. For this analysis, it is assumed that the fighter force will have 19 designated pilots total, regardless of the number of fleets involved. In addition, the number of aircraft in the fleet is assumed to include two test aircraft of each type at the Aerospace Engineering Test Establishment (AETE) but does not account for replacement of attrition aircraft. Ref. W provides an estimate of the expected number of attrition aircraft as a function of aircraft usage.

When considering mixed fleets, a straightforward way to calculate the overall fleet size begins by first determining how many Fleet A aircraft are required to satisfy the NORAD commitment and adding sufficient aircraft from Fleet B to fulfill NATO commitments. Since aircraft in Fleet B are capable of fulfilling both missions, the combined fleet now has more capability than required to meet its commitments. The optimized fleet is determined by reducing the number of Fleet A aircraft to the minimum value that allows both commitments to be satisfied. This approach may seem counterintuitive initially, particularly since it appears to prioritize NATO missions ahead of the NORAD commitment. However, the opposite is true in this case. Instead, the optimization hinges on the NATO role because it requires the more capable aircraft – so Fleet B cannot be reduced in size if both commitments are to be satisfied. The size of Fleet B therefore needs to be determined first.

As mentioned in the main body of this report, ASTRA identified that a total of 63 Fleet B aircraft and 71 pilots, not including designated pilots, were needed to sustain a rotation of six serviceable aircraft for NATO missions. This is just short of being capable of providing the 36 aircraft needed for NORAD.[14] Note that the 2:1 manning rate and 3:1 sustainment ratio mean that a substantial number of pilots are required simply to man the deployments. In addition, an assumed three year posting cycle means that the FGC must have sufficient throughput to replace one third of these pilots annually. Accounting for the flying hours these pilots require for operations and training is what drives the number of aircraft in this case.

When it was assumed that the NATO commitment would be sustained for a period of one year on six-month rotations, ASTRA determined that 38 Fleet B aircraft, along with 46 pilots, would be required. This meant that Fleet A must be able to provide 18 serviceable aircraft for the NORAD mission.[15] Using ASTRA once again, it was found that 36 Fleet A aircraft and 47 pilots would be needed to provide the required aircraft.

Table 3 shows how the number of pilots and aircraft compares for the single and mixed fleet cases considered, and how ASTRA has distributed these resources amongst the operational squadrons

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[13] Designated flying positions in the fighter force are staff positions occupied by pilots which provide an opportunity to fly enough hours to maintain currency. These pilots provide comparatively low-cost capability that can be leveraged by the Royal Canadian Air Force during critical situations, thereby resulting in a more robust fighter force.

[14] A minimum of 65 total aircraft are required to provide the 36 NORAD aircraft since 65 × 80% × 70% rounds down to 36.

[15] The 38 Fleet B aircraft are capable of providing 21 aircraft against the NORAD mission, leaving the remaining 15 to be provided by Fleet A. However, to ensure that no deployed unit contains two different types of aircraft, the demand on Fleet A is “rounded up” to 18 aircraft.

(Ops Sqns), the FGCs, and AETE. For example, the table shows that the “equal commitment”[16] mixed fleet consists of a total of 82 aircraft and 112 pilots. Of these numbers, 19 aircraft of from Fleet A are flown by 22 pilots. The remaining 90 pilots are assigned to fly the 63 Fleet B aircraft. The table also shows a hypothetical breakdown of how the squadrons would be structured in terms of pilots and aircraft.

Table 3: Resource requirements and distribution for single and mixed fleets.

Resource	Location	Single fleet	Mixed fleets: Equal commitment Total (Fleet A* + Fleet B)	Mixed fleets: Reduced commitment Total (Fleet A + Fleet B)
Aircraft	Ops Sqn 1	22	32 (11 + 21)	25 (12 + 13)
	Ops Sqn 2	23	22 (0 + 22)	25 (12 + 13)
	FGC	18	24 (6 + 18)	20 (10 + 10)
	AETE	2	4 (2 + 2)	4 (2 + 2)
	Total	65	82 (19 + 63)	74 (36 + 38)
Pilots	Ops Sqn 1	26	41 (15 + 26)	26 (13 + 13)
	Ops Sqn 2	26	26 (0 + 26)	26 (13 + 13)
	FGC	19	26 (7 + 19)	22 (11 + 11)
	Designated	19	19 (0 + 19)	19 (9 + 10)
	Total	90	112 (22 + 90)	93 (46 + 47)

* Because the number of Fleet A aircraft is small, only a single operational squadron was used.

COST ANALYSIS

A RAND doctoral thesis showed that for US Air Force fleets, economies of scale are such that a doubling of fleet flying hours[17] only resulted in a 56% increase in operations and sustainment (O&S) costs, minus fuel costs (Ref. S). A subsequent analysis found that the increase is smaller for US combat aircraft (Ref. T). The increase in costs due to losses in economies of scale are very significant; the US DOD recently reported that at least 70% of life cycle costs are expended after the acquisition of a weapon system (Ref. X). This is consistent with Department of National Defence costing estimates for the Joint Strike Fighter[18] (Ref. Y) as well as a recent report from the Special Adviser to the Minister of Public Works and Government Services (Ref. Z).

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[16] The terms “equal commitment” and “reduced commitment” are used to describe the mixed fleets’ ability to sustain a NATO deployment relative to the single fleet.

[17] Fleet size and flying hours are very closely correlated, for fairly obvious reasons. Therefore, conclusions drawn about flying hours generally hold for fleet size as well.

[18] The 2012 report estimated that O&S will account for $35.2 billion of the $44.82 billion life cycle cost, or approximately 79%. Based on the 2013 report, this figure is slightly revised to 78%, or $34.912 billion out of a total life cycle cost of $44.676 billion.

The ratio of O&S costs relative to the full life cycle costs for the single fleet of 65 aircraft is estimated using a triangular distribution with 78% as the most likely value, 70% as the minimum value, and for symmetry 86% as the maximum. The acquisition cost of the 38 Fleet B aircraft in the mixed fleet is assumed to be 38/65 of the cost of the single fleet's acquisition cost, although it is quite possible that the per unit acquisition cost could go up if fewer aircraft were purchased. Ref. S is used to estimate the O&S costs for the sub-fleet of 38 Fleet B aircraft. From Ref. S, the cost scales by a factor of approximately 1.56 as the fleet size doubles. Ref. T shows that it is in the range 1.37–1.50 for fighter aircraft. These values form the basis for another triangular distribution on which the O&S cost of the Fleet B aircraft is based. The cost of 34 Fleet A aircraft is estimated in the same way as the single fleet. The acquisition cost of a single Fleet A aircraft is then varied to see when half the simulation cases result in the single fleet being the more expensive of the two options and half the simulation cases resulting in the mixed fleet being more costly.