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# Fiscal Analysis of the Interim F-18 Aircraft

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The Parliamentary Budget Officer (PBO) supports Parliament by providing economic and financial analysis for the purposes of raising the quality of parliamentary debate and promoting greater budget transparency and accountability.

This report presents a fiscal analysis of the Government of Canada's purchase of 18 used F-18 aircraft from Australia.

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# Executive Summary

This report provides an independent estimate of the impact of the costs of Canada's procurement of 18 Australian F/A-18 aircraft on the federal budget. This captures all costs associated with the procurement and remaining life cycle of these aircraft, taking into consideration the total cost of project development, acquisition, operations, and disposal, while accounting for risks and sensitivities.

The findings of this report are as follows: the risk-adjusted life cycle cost estimate of the Interim Fighter Capability Project is approximately $1.09 billion, with a low-end estimate of $1.08 billion and a high-end estimate of $1.15 billion.[1] Breaking this down into the project's phases, PBO has estimated a Development phase cost of $12.5 million, an Acquisition phase cost of $311.5 million, an Operations and Sustainment phase cost of $756.5 million, and a Disposal phase cost of $11 million.

The total estimated life cycle cost of 1.09 billion is some 22% higher than the Department of National Defence (DND) estimate. This is largely driven by costs in the operations and sustainment phase, where the PBO has estimated life extension and upgrade costs that are approximately $120M higher than DND's.

Sensitivity analysis surrounding changes in planned flying rates show that the total project life cycle cost estimate can vary by as much as $55.5 million. A delay in the completion of the acquisition phase by one year, such that deliveries of six aircraft slip into the 2022-2023 fiscal year, would increase total project costs by $12.5 million.

A comparison of DND's reported life cycle costs is given in Summary Table 1.

Summary Table 1 Comparing DND's reported costs[2] with PBO estimates

| Source | Development | Acquistion | Operations and Sustainment | Disposal | Total |
|---|---|---|---|---|---|
| **DND Estimates** | $12.5 M | $298.5 M[a] | $584.5 M[b] including disposal costs | - | $895.5 M |
| **PBO Estimates** | $12.5 M | $311.5 M | $756.5 M | $11 M | $1,091.5 M |

a. DND's Acquisition total of $298.5 M excludes a contingency of $50 M.
b. DND's Operations and Sustainment total of $584.5 M excludes a contingency of $83.5 M.
Figures rounded to nearest $0.5 million.

Source: Department of National Defence, Parliamentary Budget Officer.

Compared to procurements of new weapons systems, such as the Surface Combatant or the Future Fighter capabilities, this project is both less risky and significantly less costly. From a risk perspective, the 35-plus years of experience the Royal Canadian Air Force (RCAF) has accumulated in managing the existing CF-18 fleet ensures a fair amount of cost certainty with regards to maintenance, provisioning, and upgrades, even as the fleet continues to age. From a cost perspective, the aircraft being purchased are used and in similar condition and configuration to the current fleet; these factors lead to a relatively low purchase and modification cost and obviate the need for extensive changes to the RCAF's existing infrastructure.

# 1. Introduction

This report provides an independent estimate of the impact of the costs of Canada's procurement of 18 Australian F/A-18 aircraft on the federal budget. This estimate is for a total life cycle cost, thus taking into consideration the total cost of project development, acquisition, operations and sustainment, and disposal of the additional aircraft.

For each project phase, we consider potential risks and model their impacts on costs in order to arrive at a risk-adjusted cost estimate.[3] We also conduct sensitivity analysis for the effect of delays in acquisition and the possibility of variation in flying rates for the fleet over time.

Finally, we compare the findings of this report to the cost estimates provided by the Department of National Defence (DND).

## 1.1. Background

On November 22, 2016, the Government of Canada announced its intention to launch an open and transparent competition to replace the RCAF's aging fleet of CF-18 fighter aircraft. By this time, the fleet was over 30 years old, and the number of operable aircraft had been reduced from the initially procured 138 aircraft to 77.[4]

Citing a capability gap and the ongoing need to respond to NATO and NORAD commitments, the government launched the Interim Fighter Capability Project. At the same time, it reserved the right to explore options for rapidly obtaining supplementary fighter aircraft, initially targeting the acquisition of 18 F-18E/F Super Hornets from the U.S.-based Boeing.

Since this time, the government has instead moved towards an alternate solution, announcing its intention to purchase 18 second-hand legacy F/A-18 Hornets from Australia on December 12, 2017. The deal was signed on November 9, 2018.[5]

The Department of National Defence estimates a total cost of $471 million (all figures CAD) for the acquisition phase of the project, which includes approximately $12.5 million for the project development phase and $110 million for upgrades and life extension. It also estimated a cost of $558 million for the operation and sustainment of the 18 additional aircraft until their disposal in 2032. Following this, the Future Fighter Capability Project (FFCP) will be concluded and a new fleet of 88 fighter jets would be at full operational capacity.[6]

Table 1-1 presents DND's estimates. Here, the $12.5 million for project development is separated into the "Development" phase. The $110 million for upgrades and life extension is included in the Operations and Sustainment phase, as these will occur on an ongoing basis and not only during the Acquisition phase. We also exclude contingency funds of $50 million in the Acquisition phase and $83.5 million in the Operations and Sustainment phase in order to accurately present the point estimates of project costs.

Table 1-1 DND's life cycle cost estimates

| Source | Development | Acquistion | Operations and Sustainment | Total |
|---|---|---|---|---|
| **DND Estimates** | $12.5 M | $298.5 M[a] | $584.5 M[b] including disposal costs | $895.5 M |

a. DND's Acquisition total of $298.5 M excludes a contingency of $50 M.
b. DND's Operations and Sustainment total of $584.5 M excludes a contingency of $83.5 M.
Figures rounded to nearest $0.5 million.

Source: Department of National Defence.

Canada has already begun receiving deliveries of the Australian F/A-18 aircraft; the delivery schedule will conclude in 2021-2022 fiscal year.

## 1.2. Scope of Analysis

This analysis develops a total *incremental* cost for the plan to purchase 18 Australian F/A-18 aircraft, including *life cycle* costs covering the period from the project development phase to the eventual disposal of the aircraft.

**Incremental costs** are costs related directly to a given project above baseline or pre-existing costs that would be incurred in any case. Thus, incremental costs would include categories such as research and development specific to a project, the maintenance costs of a military system, and costs associated with system usage. Costs associated with maintaining pre-existing infrastructure, salaries of personnel who would be employed regardless, and fixed base-level costs would not be included in incremental costs.

**Life cycle costs** capture all costs associated with a project from the initial concept formulation stage through the project's entire useful life. In the case of a military weapons system, life cycle costs can be divided into four distinct phases: Development, Acquisition, Operations and Sustainment, and Disposal.[7] Briefly, these phases are summarized as follows:

- **Development**: all activities leading up to the purchase of a given weapon system, such as options analysis, infrastructure studies, and research and development.

- **Acquisition**: consists of the purchase of the system and its integration into service and full operational capability.

- **Operations and Sustainment**: includes all activities relating to the usage, support and maintenance of the system.

- **Disposal**: activities associated with the withdrawal of the system from service at the end of its useful life.

The purpose of limiting the analysis to considering incremental life cycle costs is to provide an accurate representation of the total additional costs that must be incurred due to the procurement.

In the context of the present analysis of Canada’s acquisition of Australian F/A-18 fighter aircraft, incremental life cycle costs include:

- All costs associated with project development activities;
- All costs associated with the procurement, integration and standardization (i.e., “Canadianization”) of the aircraft;
- All maintenance and munitions costs, ongoing system improvement and life extension costs (“betterment” costs), and petroleum, oil and lubricant costs; and
- All applicable costs related to disposal at the end of the aircraft’s useful life; costs would include dismantling the aircraft and disposing of the components, including properly disposing of sensitive and hazardous material.

A detailed description of the included cost elements is provided in Section 3.2.

## 1.3. Project Specifications

The specifications of the Interim Fighter Capability Project are as follows:

- Acquire 18 flyable F/A-18 aircraft including associated spare parts and ancillary equipment;
- Acquire up to seven non-flyable spare aircraft as assembled spares or training aids;
- Modify the flyable aircraft to ensure concordance with the existing Canadian fleet;

- Apply life extension and capability modifications on an ongoing basis in concert with the existing Canadian fleet; and
- The fleet is phased out by the 2032-2033 fiscal year, with each aircraft being in operation for about 10 years.[8]

## 1.4. PBO Assumptions

- The PBO estimate of the cost of the project's Operations and Sustainment phase, notably maintenance and munitions costs and betterment costs, rests on the assumption that historical cost estimating relationships will continue to hold over time;
- The fleet arrival profile consists of 2 aircraft in 2018-2019, 2 aircraft in 2019-2020, 8 aircraft in 2020-2021, and 6 aircraft in 2021-2022;
- The aircraft will enter service approximately 6 months after being received;
- The aircraft will each accumulate about 160 flying hours per year, in accordance with the recent experience of the Canadian CF-18 fleet;
- Each Australian F/A-18 has accumulated an average of 6000 flying hours over the course of its operational history with the Royal Australian Air Force;
- There is no attrition, that is, removal from service or early disposal prior to the planned phase-out date of 2032-2033;
- The number of assembled spare aircraft to be acquired is 2, with a contract option to procure up to a total of 7; and
- Costs associated with the upgrade and ongoing improvement of the additional aircraft are rolled into the Operations and Sustainment phase.

# 2. Methods and Data

The methods we employ to estimate the life cycle cost vary according to the project phase, the types of activities involved, and the PBO assessment of the level of cost certainty. This section briefly summarizes the methods and data used to estimate costs and risks for each phase. The methods are described in greater detail in Appendix B.

## Development Phase

The Development phase is currently nearing completion. We therefore assess the cost certainty of this phase as very high and base the PBO cost estimate strictly on DND inputs. There are no assessed risks or sensitivities associated with this phase.

## Acquisition Phase

The Acquisition phase is underway, with the first deliveries occurring earlier this month (February 2019). A portion of acquisition costs is governed by firm, fixed contracts; as such, these costs are rated as being certain. The figures provided by DND are used in the PBO estimate.

### What is Inflation Risk?

Inflation risk refers to the possibility that the price level in the economy changes at a rate that is different than the projection used to calculate costs. A higher rate of inflation over time would increase total costs, while a lower rate would decrease costs.

There are two classes of risks associated with the Acquisition phase. The first is financial risk, which includes inflation risk and foreign exchange rate risk. The second is project-level risk, which includes risks associated with project activities; these are: the amount of engineering work required to bring the Australian aircraft up to the RCAF standard, the amount of assembled spare aircraft to be purchased, and the possibility of receiving Australian tax incentives tied to the delivery schedule timeline. These are all modelled using simulation methods to estimate the impact on Acquisition phase costs and are factored into the phase's risk-adjusted cost estimate.

Sensitivity analysis for the Acquisition phase assesses the possible impact on costs of a one-year delay in the completion of aircraft deliveries.

## Operations and Sustainment Phase

The Operations and Sustainment phase is due to begin with the arrival and entry into service of the first Australian F/A-18 aircraft. It is the longest and costliest life cycle phase and contains the greatest exposure to risk as costs are affected by external factors such as inflation and fuel prices.

There are three categories of costs associated with this phase: maintenance and munitions costs, betterment costs, and petroleum, oil and lubricant costs.

Maintenance and munitions costs are estimated using regression analysis on historical data and deriving a cost estimating relationship between flying rates, number of aircraft, and costs. A separate regression model is constructed to estimate betterment costs, which relates total cumulative flying hours over an airframe's lifetime to betterment costs.

### Data Sources

PBO has obtained historical data on National Procurement (NP) and Betterment costs from the Department of National Defence and other sources.[9] The data set upon which this analysis is based covers the entire life of the CF-18 fleet up to the 2017-2018 fiscal year.[10]

### National Procurement Data

DND's "National Procurement" budget accounts for the cost of spares, maintenance material, equipment overhaul, munitions, and contracts with foreign governments and private companies for maintenance. As such, it captures virtually all incremental munitions and maintenance-related costs associated with the CF-18 fleet. One potential exception is labour costs at the intermediate maintenance level, which are not included. There is therefore the possibility that maintenance costs, as defined by NP data, are slightly underestimated in this analysis.[11]

### Betterment Data

According to DND's Financial Administration Manual,[12] a betterment:

> "appreciably improves, enhances or extends the service potential of an existing TCA (Tangible Capital Asset) by meeting at least one of the following criteria:
>
> (a) Increasing the capital asset's previously assessed physical output or service capacity;
>
> (b) Improving the capital asset's performance and quality of output;
>
> (c) Reducing the capital asset's operating costs; or
>
> (d) Increasing the useful life of the whole asset by one year or more."

As such, this class of costs accurately accounts for the ongoing system improvement cost category as well as costs associated with the CF-18s current life cycle extension program which are to be applied to the incoming Australian aircraft.

Source: Department of National Defence.

Petroleum, oil and lubricant costs are calculated by combining historical burn rates per flying hour with costs per litre and projecting total costs over the assumed flight profile of 160 hours per aircraft per year.

The primary risks associated with the Operations and Sustainment phase are inflation risk and petroleum, oil and lubricant price risk. These are each modelled via simulation methods and the estimated exposures are internalized in the phase's risk-adjusted cost estimate.

We also explicitly model the level of uncertainty arising from the regression models used to estimate maintenance and munitions costs and betterment costs.

Finally, we conduct a sensitivity analysis to estimate the changes in Operations and Sustainment phase costs due to variations in the planned per-aircraft yearly flying rates.

## Disposal Phase

The Disposal phase occurs at the end of the service life of the additional 18 aircraft. We have assumed that the disposal phase proceeds in a staggered fashion, mirroring the entry into service of the aircraft. To calculate the total cost associated with this phase, we use inputs and projections provided by DND on the cost of total CF-18 fleet disposal and attribute costs proportionally to the subset of 18 aircraft. Given DND's experience in CF-18 aircraft disposal, we consider these costs to be certain, and no additional risk elements are included.

# 3. Results

This section details the results of the costing analysis. The main estimates of the total life cycle costs, including adjustments for the risk categories identified in this report, are presented first. This is followed by a breakdown of each phase's cost totals, a listing of the applicable cost elements, and an analysis of phase-specific cost risks.

## 3.1. Life Cycle Fiscal Analysis

PBO estimates the total life cycle cost of the 18 additional legacy F-18 aircraft at $1.09 billion on a risk-adjusted basis.[13] Figure 3-1 displays the cumulative cost distribution of the project's life cycle, inclusive of the Development, Acquisition, Operations and Sustainment, and Disposal phases, and all assessed risk elements. The low-end life cycle cost, evaluated at the 40$^{th}$ percentile of the cost distribution, is $1.08 billion, while the high-end, evaluated at the 80$^{th}$ percentile, is $1.15 billion.[14]

Table 3-1 Life cycle cost estimates

| **Low Estimate** (40$^{th}$ Percentile) | **Main Estimate** (50$^{th}$ Percentile) | **High Estimate** (80$^{th}$ Percentile) |
|---|---|---|
| $1.08 B | $1.09 B | $1.15 B |

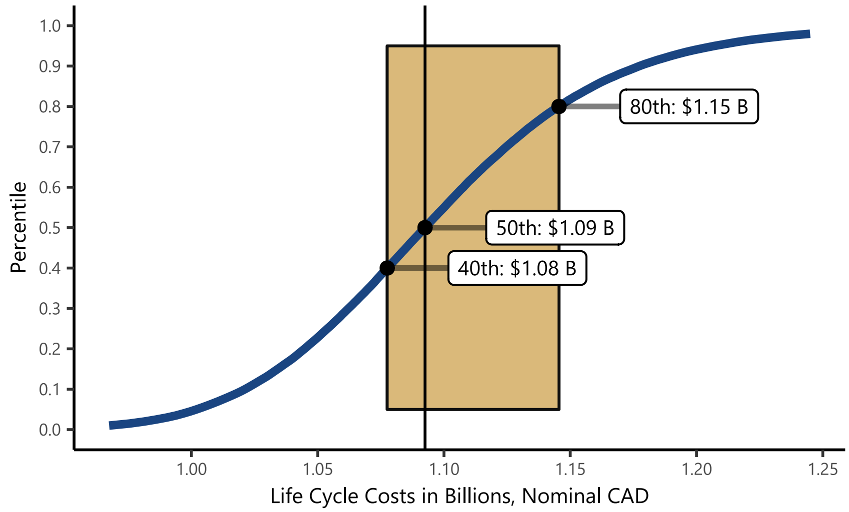
Figures rounded to nearest $10 million.

Figure 3-1

Life cycle cost curve

Understanding cost curves

This graph displays the cumulative distribution of life cycle costs. The percentiles (y-axis) indicate the likelihood of a certain cost being achieved once all identified risks are taken into account. In this case, there is a 40% likelihood that costs will not exceed $1.08 B, a 50% likelihood costs will not exceed $1.09 B, and an 80% likelihood costs will not exceed $1.15 B.




Source: Parliamentary Budget Officer

## 3.2. Breakdown of Life Cycle Phases

### Development Phase Costs

The costs associated with the Project Management element in the Development phase total $12.5 M. As the development phase is nearing completion, it does not have any risk.

Table 3-2 Development Phase Cost Elements

| Development Phase Cost Element | Cost (rounded, not risk-adjusted) |
|---|---|
| **Project Management** | $12.5 M |

### Acquisition Phase Costs

The risk-adjusted cost estimate of the Acquisition Phase is $311.5 M.

The non-risk adjusted cost estimate is $294 million; a breakdown of the individual elements is given in Table 3-3.

Table 3-3 Acquisition Phase Cost Elements

| Acquisition Phase Cost Element | Cost *(rounded, not risk-adjusted)* |
|---|---|
| **Project Management** | $16 M |
| **Infrastructure** | $42 M |
| **Total Purchase, Engine Repair and Overhaul, and Spares** | $127 M |
| **Modifications and Canadianization** | $16 M |
| **Support Systems** | $2 M |
| **System Engineering and Test, Trials and Evaluation** | $64 M |
| **Sustainment Set-Up** | $8 M |
| **Deployment** | $19 M |
| **Total:** | $294 M |

## Acquisition Phase Risk Analysis

The risk elements for the Acquisition phase are divided into two classes:

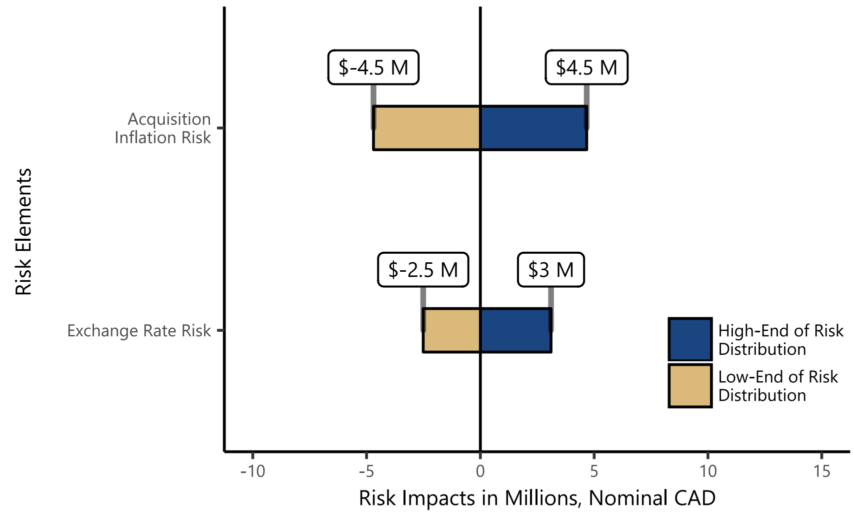
- **Financial risks**, accounting for inflationary and foreign exchange rate risks; and
- **Project risks**, which include risk associated with the cost of the initial engine repair and overhaul, the number of assembled spare aircraft to be purchased, and the potential savings from the Australian tax incentives.[15]

Figure 3-2 displays the tornado chart of the potential impact of variations in the expected level of inflation and the volatility of the AUD-CAD exchange rate. Acquisition phase inflation risk can reduce or increase costs by as much as 4.5 million at the 25$^{th}$ and 75$^{th}$ probability percentiles, respectively. Exchange rate risk, meanwhile, can result in a potential savings of $2.5 million at the 25$^{th}$ percentile and an increase in costs of $3 million at the 75$^{th}$ percentile.

## Figure 3-2 Potential impacts of inflation and exchange rate risk on estimated acquisition phase costs

### Understanding tornado charts

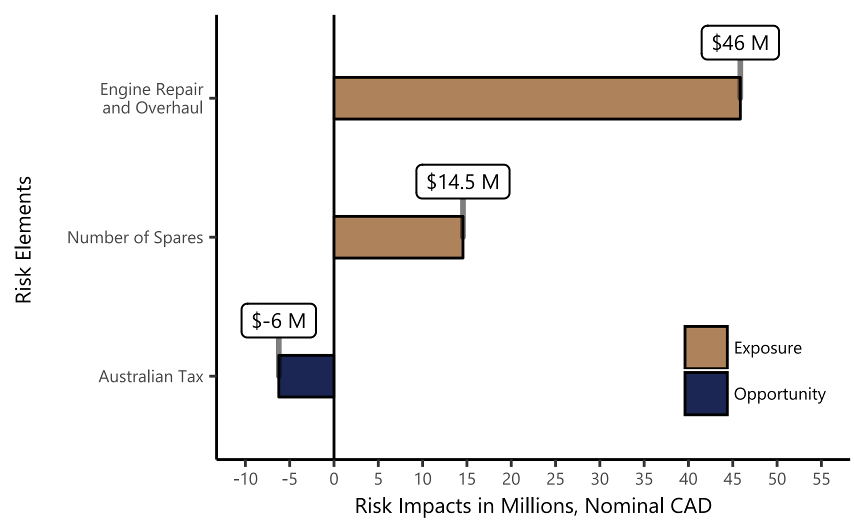
A tornado chart is a type of bar chart that displays the potential impacts of certain classes of risks on the cost estimate. Bars to the left of the zero axis indicate possible cost savings, while bars to the right of the axis indicate potential increases in costs.




Source: Parliamentary Budget Officer

Figure 3-3 depicts the exposures and opportunities associated with the Acquisition phase's project-level risks. Costs associated with the Engine Repair and Overhaul element can increase by up to $46 million. Procuring additional spare aircraft above the 2 already assumed in the Acquisition phase cost estimate can increase costs by up to $14.5 million. Savings due to Australian tax incentives can total $6 million.

## Figure 3-3 Potential impacts of inflation and exchange rate risk on estimated acquisition phase costs




Source: Parliamentary Budget Officer

# Operations and Sustainment Phase Costs

The risk-adjusted cost estimate of the Operations and Sustainment Phase is $756.5 million.

Without accounting for risks, costs for the phase are estimated at $750.5 million. Table 3-4 displays point estimates for maintenance and munitions costs, betterment costs, and petroleum, oil and lubricant costs.

**Table 3-4** Operations and Sustainment Phase Cost Elements

| Operations and Sustainment Phase Cost Element | Cost *(rounded, not risk-adjusted)* |
|---|---|
| **Maintenance and Munitions**[16] | $422 M |
| **Betterment**[17] | $226 M |
| **Petroleum, Oil and Lubricant** | $102.5 M |
| **Total:** | $750.5 M |

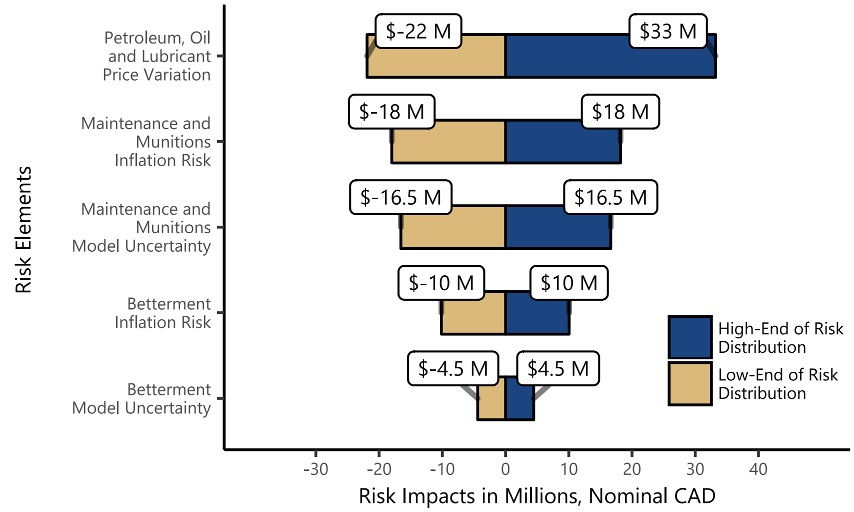
On a non-risk-adjusted basis, PBO has estimated that the cost of maintaining and providing munitions for the additional 18 aircraft throughout their remaining life is $422 million. Betterment costs, which largely reflect modifications and upgrades to extend the life of the aircraft, will cost $226 million. Petroleum, oil and lubricant costs are estimated at $102.5 million before accounting for price risk.

# Operations and Sustainment Phase Risk Analysis

Figure 3-4 depicts the associated potential impacts of risk elements and model uncertainties on the Operations and Sustainment phase cost estimate. Petroleum, oil and lubricant price fluctuations account for the largest risk category, with a potential savings, evaluated at the 25$^{th}$ percentile, of $22 million, and a potential exposure of $33 million at the 75$^{th}$ percentile. Deviations from the projected inflation rate can affect the costs of the maintenance and munitions cost category by plus or minus $18 million and the betterment cost category by plus or minus $10 million.

The uncertainty associated with the maintenance and munitions model results in an imprecision of about $16.5 million in either direction at the 25$^{th}$ and 75$^{th}$ percentiles, while Betterment model uncertainty can affect the estimate by plus or minus $4.5 million.

Figure 3-4 **Potential impacts of risks and model uncertainties on estimated Operations and Sustainment phase costs**




Source: Parliamentary Budget Officer

## Disposal Phase Costs

Disposal costs include those associated with the dismantling and demilitarization of the aircraft and disposing of the components. PBO estimates the total cost of this phase at $11 million.

Table 3-5 **Disposal Phase Cost Elements**

| Disposal Phase Cost Element | Cost (rounded, not risk-adjusted) |
| --- | --- |
| **Dismantling, demilitarization, disposal** | $11 M |

# 4. Sensitivity Analysis

We consider two potential scenarios and examine the effect on total life cycle costs: a one-year delay in procurement, with an associated extension of the planned phase-out date, and the impact on life cycle costs of changes in fleetwide flying hours.

## 4.1. A One-Year Delay in Procurement

First, we consider the total impact of a one-year delay in completing the acquisition phase. We calculate this cost by changing the fleet arrival profile to reflect a slippage of a total of 6 aircraft to the 2022-2023 fiscal year and observing the impact on life cycle costs.

Table 4-1 **Current fleet arrival profile compared to profile with one year delay (number of aircraft per year)**

| | 2018-2019 | 2019-2020 | 2020-2021 | 2021-2022 | 2022-2023 |
|---|---|---|---|---|---|
| **Current Profile** | 2 | 2 | 8 | 6 | 0 |
| **1-Year Delay** | 2 | 1 | 5 | 4 | 6 |

Source: Assumption of the Parliamentary Budget Officer

There are two associated cost impacts, the first affecting Acquisition phase costs due to the increases in inflation rates and the associated inflation rate and exchange rate risk, and the second affecting Operations and Sustainment phase costs due to the longer flying profile and the associated inflation and petroleum, oil and lubricant price risks. Taken together, a 1-year delay in completing the Acquisition phase will add an additional $12.5 million to the project's life cycle cost on a risk-adjusted basis.

Table 4-2 **The cost of one year delay**

| | |
|---|---|
| **Acquisition Phase** | $4 M |
| **Operations and Sustainment Phase** | $8.5 M |
| **Total Cost** | $12.5 M |

Note: These figures are adjusted for risk.

## 4.2. Changes in Yearly Flying Rates

The recent experience of the CF-18 fleet has demonstrated variability in the average number of flying hours per year on a per-aircraft basis, ranging from 130 per year to 190 per year since 2004. To examine the effect that ongoing changes in flying rates may have on the total lifecycle cost, we adjust the yearly flying hour assumptions in our model and determine the total costs associated with both a low flying rate (-25%) and high flying rate (+25%). The results of this sensitivity analysis are given in Table 4-3.

**Table 4-3** **The effect of changes in flying hour assumptions on life cycle costs**

| Low Flying Rate | High Flying Rate |
|---|---|
| -$55.5 M | $55.5 M |

Note: These figures are adjusted for risk.

# 5. Comparison to DND Estimates

The Department of National Defence reported in November of 2018 that the total acquisition cost of the Australian F/A-18 would be $471 million, while support costs through the phase-out of the fleet would total $558 million.[18] DND includes Development phase costs in the reported total acquisition costs, while Disposal phase costs are included in the reported support costs.

To arrive at a fair comparison, we shift $110 million reported within the acquisition total of $471 million to the Operations and Sustainment phase as it concerns the upgrade and life extension of the 18 aircraft. This leaves a total of $361 million in Acquisition, which also includes a contingency fund of $50 million and approximately $12.5 million associated with Development phase costs. Shifting this $12.5 million to the Development phase and removing the contingency leave $298.5 million, which is reasonably close to the PBO estimate of $311.5 million in this report. This similarity is due to the use of DND inputs for the Acquisition phase, which were assessed both as being of good quality and relatively low uncertainty.

DND's operations phase costs, which include disposal costs, total $558 million. This amount contains a 15% contingency, or approximately $83.5 million; the total without contingency is $474.5 million. Adding the $110 million for planned upgrades and life extension, the total for the phase is $584.5 million. The PBO estimate for the operations and sustainment phase, excluding disposal costs, is $756.5 million and does not include contingency. We separately estimate disposal phase costs at approximately $11 million.

**Table 5-1 Comparing DND's reported costs with PBO estimates**

| Source | Development | Acquistion | Operations and Sustainment | Disposal | Total |
|---|---|---|---|---|---|
| **DND Estimates** | $12.5 M | $298.5 M[a] | $584.5 M[b] including disposal costs | - | $895.5 M |
| **PBO Estimates** | $12.5 M | $311.5 M | $756.5 M | $11 M | $1,091.5 M |

a. DND's Acquisition total of $298.5 M excludes a contingency of $50 M.
b. DND's Operations and Sustainment total of $584.5 M excludes a contingency of $83.5 M.
Figures rounded to nearest $0.5 million.

Sources: Department of National Defence, Parliamentary Budget Officer.

The PBO therefore estimates a total life cycle cost of approximately $1.09 billion. This is some 22% higher than DND's life cycle cost estimate of $895.5 million. This is largely driven by costs in the operations and sustainment phase, where the PBO has estimated life extension and upgrade costs that are approximately $120M higher than DND's.

Finally, the sensitivity analysis conducted within this report shows that prices could further change according to both project timelines and future flying hour behaviour within the fleet. Employing relatively conservative assumptions with regards to these factors, total life cycle costs could either be decreased by up to $55.5 million or increased up to $68 million.

# Appendix A: Comparing the Australian and Canadian Fleets

Introduced into service in a five-year span from 1985 to 1990, Australia has operated the F-18A/B fighter fleet continuously since that time. The Australian fleet has undergone extensive systems and weapons upgrades and structural refurbishments over the course of its life cycle; the Australian National Audit Office (ANAO) estimated in a 2012 report that the Australian Government will have spent $3.7 billion (then-year AUD) by 2015 over the preceding two decades for these purposes.[19]

By 2012, the Australian fleet had accumulated a total of 306,000 flying hours in total across 71 aircraft. The ANAO predicted that the fleet would reach the end of its "safe life" of 6,000 hours per aircraft[20] after 2020, which was then the Planned Withdrawal Date. Currently, the Australian Air Force is beginning a drawdown of its F/A-18 fleet, aiming to fully transition to its F-35 Joint Strike Fighter capability by 2023.

Canada began acquiring the CF-18 in 1982 and received its final deliveries in 1989, obtaining a total of 138 aircraft. The Canadian fleet has also undergone extensive system improvements and upgrades over the course of its service life, including two phases of incremental improvements for a total cost of $2.6 billion (then-year dollars), with the last phase being completed in 2010.

According to PBO calculations, the Canadian fleet is both slightly older and has experienced more usage than the Australian fleet. The average Canadian F-18 had accrued over 6,000 flying hours by the end of the 2017-2018 fiscal year. These calculations are supported by media reports indicating that by 2014, the CF-18s had accumulated over 5,700 flying hours on average, with over a third of the fleet already having flown over 6,000.[21]

Canada's Department of National Defence has stated that the aircraft being purchased from Australia's F-18 fleet are very similar to those currently in operation within the RCAF, stating, "Australian fighter aircraft have a similar configuration to Canada's CF-18s and will require few changes to meet the needs of the women and men of the Royal Canadian Air Force to carry out their missions, including Canada's NATO and NORAD commitments."[22] The length of time associated with the modifications and concordance of the incoming Australian aircraft is not expected to exceed 6 months for each aircraft.[23]

# Appendix B: Details on Methodology

This Appendix provides additional detail on the methods used to estimate costs while accounting for risk, uncertainty, and sensitivities associated with each project phase.

## B.1 Development Phase

### Table B-1 Development phase cost elements and risks

| | |
|---|---|
| **Cost Elements:** | Project Management |
| **Risks:** | None |

The Development phase is nearing completion as the project moves into the Acquisition phase. The figures provided by DND have been assessed by the PBO and are considered appropriate; they are therefore directly included in the life cycle cost estimate.

## B.2 Acquisition Phase

### Table B-2 Acquisition phase cost elements, risks, opportunities and sensitivities

| | |
|---|---|
| **Cost Elements:** | Project Management, Infrastructure, Total Purchase Cost, Engine Repair and Overhaul, Spares, Modifications and Canadianization, Support Systems, System Engineering and Test, Trials and Evaluation, Sustainment Set-Up, Deployment |
| **Risks:** | Inflation Risk, Foreign Exchange Rate Risk, Engine Repair and Overhaul, Number of Spares |
| **Opportunity:** | Australian Tax Incentives |
| **Sensitivity:** | Delays in delivery schedule |

The Acquisition phase is underway, with deliveries having begun in February 2019. A portion of acquisition costs is governed by firm, fixed contracts; as such, these costs are rated as being certain. The figures provided by DND are used in the cost estimate.

## Risk: Inflation

The impact of inflation risk on the Acquisition phase cost estimate is determined by modelling deviations from the PBO forecasted inflation rate and observing the resulting impact on costs.

Established DND practices in past defence materiel procurement projects have used a plus-or-minus one percent approach to modelling inflation risk.[24] Our analysis innovates on this approach. Similar to the DND method, we use a "low" and "high"-end projection of inflation rates that are one percent below and above the PBO baseline estimate. However, we then use these as baselines for the 10th and 90th percentiles of a Normal distribution of possible inflation outcomes for the year, and model the impacts on costs using a Monte Carlo simulation approach. This method allows for the possibility that inflation deviations greater than one percent can occur, while not unduly putting weight on these large deviations.

Table B-3 **Example of PBO inflation risk modelling method**

| | 2020-2021 | 2021-2022 | 2022-2023 | 2023-2024 |
|---|---|---|---|---|
| **High-End** | 3.09% | 3.07% | 3.05% | 3.02% |
| **PBO Baseline** | 2.09% | 2.07% | 2.05% | 2.02% |
| **Low-End** | 1.09% | 1.07% | 1.05% | 1.02% |

## Risk: Foreign Exchange Rate Exposure

Foreign exchange rate risk also figures into the Acquisition phase. The Government of Canada is paying for the fighter aircraft in Australian dollars, and the timing of payments is coordinated with the delivery schedule. There is also a small amount of foreign exchange risk relating to purchases of components from the United States. To determine the potential impact of these risks on Acquisition phase costs, we model potential changes in the AUD-CAD (Australian Dollars valued in Canadian Dollars) and USD-CAD (US Dollars valued in Canadian Dollars) using historical volatility estimates and the root-of-time method. Potential exposures are therefore determined by the amount of time to be elapsed before the payment must occur and the historical behaviour of the volatility of the exchange rate.

## Risk: Engineering Costs

There also exists uncertainty in terms of the cost of the engineering changes, notably in terms of the amount of work and material required to repair and overhaul the engines of the 18 flyable aircraft. For this risk category, we simulate a cost distribution based on DND assessments by subject matter experts.

### Opportunity: Australian Tax Incentives

The procurement agreement with Australia also includes tax incentives that could result in savings if the agreed upon timelines are respected. We model these potential savings using inputs from DND's own risk analysis; savings could total up to $6 million.

## B.3 Operations and Sustainment Phase

**Table B-4** Operations and Sustainment phase cost elements, risks, and sensitivities

| | |
|---|---|
| **Cost Elements:** | Maintenance and munitions, Betterment, Petroleum, oil and lubricant costs |
| **Risks:** | Inflation risk, petroleum, oil and lubricant price risk |
| **Sensitivity:** | Changes in yearly flying rates |

The Operations and Sustainment phase has not yet begun and will have a duration of over 12 years, ending with the planned withdrawal from service of the CF-18 fleet in 2032-2033. Several risk categories are relevant to the Operations and Sustainment phase: inflation risk, which is the risk that the rate of the rise in the price level exceeds (or falls short of) PBO projections; and petroleum, oil and lubricant price risk, which occurs due to the deviation in costs of fuel and lubricant over time.

### Estimating Maintenance and Munitions Costs and Betterment Costs

To develop estimates of the "maintenance and munitions" and "betterment" cost elements over the remaining life of the additional F-18s, PBO adopts a modelling approach based on the concept of Cost Estimating Relationships (CERs). This method involves estimating a cost by relying upon an established relationship between costs and one or more "cost drivers", or factors that affect or explain these costs. These relationships can be identified and quantified through multiple regression analysis. Once established, the modelled relationships are used to generate out-of-sample cost estimates based on the established flying rate profile.

We build regression models for maintenance and munitions costs and betterment costs separately, since it is plausible that these phenomena are explained by differing factors. We employ the following model specifications:

$$Fleet\ Maintenance\ and\ Munitions\ Costs = f(flying\ hours, number\ of\ aircraft)$$

$$Betterment\ Costs\ per\ Aircraft = f(number\ of\ cumulative\ flying\ hours)$$

The maintenance and munitions model therefore relates costs to the number of flying hours per year and the total number of aircraft in the fleet. Betterment costs are estimated as a function of the number of cumulative flying hours experienced by a given airframe over the course of its life cycle.

The maintenance and munitions model also accounts for fixed, fleet-wide costs. This cost is deducted from the calculation of the maintenance and munitions cost estimate as it is not incremental in nature and would be incurred regardless of the inclusion of the additional 18 aircraft.

## Regression Results

**Maintenance and Munitions Cost Model**

### Table B-5 Maintenance and munitions cost model results

| Variable | Coefficient |
|---|---|
| Intercept | 24,013,169 |
| Fleetwide Flying Hours per Year | 2,480 ** |
| Total Number of Aircraft in Fleet | 1,586,542 *** |
| Joint Significance (p-value) | 0.0000000003809 |
| Adjusted R-Squared | 0.7261 |

Notes:
* indicates a significance level under 0.1, ** indicates a significance level under 0.05, and *** indicates a significance level under 0.01.
The dependent variable is yearly maintenance and provisioning costs for the entire fleet.

Source: Parliamentary Budget Officer

The maintenance and munitions cost model thus finds a fixed, fleet-wide cost of $24 million per year; yearly fleet-wide flying hours increase costs by $2,480 per flying hour; and each aircraft has a base maintenance and munitions cost of approximately $1.6 million. These figures are inflated to the 2017-2018 fiscal year and are not adjusted for risk.

**Betterment Cost Model**

## Table B-6 Betterment cost model results

| Variable | Coefficient |
|---|---|
| Intercept | -254,017.39 ** |
| Cumulative Lifetime Flying Hours | 154.28 *** |
| Joint Significance (p-value) | 0.0000008194 |
| Adjusted R-Squared | 0.6971 |

Notes:
* indicates a significance level under 0.1, ** indicates a significance level under 0.05, and *** indicates a significance level under 0.01.
The dependent variable is yearly betterment costs per aircraft.

Source: Parliamentary Budget Officer

The Betterment model forecasts costs on a per-aircraft basis rather than for the entire fleet as the modelling process finds no evidence of a fixed, fleet-wide relationship for betterment costs. Constructing a model that relates cumulative flying hours and average per-aircraft betterment costs results in a precise statistical relationship.

The model finds that Betterment costs only begin to accrue once an aircraft has accumulated about 1,650 flying hours over the course of its life; prior to this point, there is a cost savings. After 1,650 flying hours, Betterment costs are increased by $154.28 per year per flying hour accumulated. The Australian aircraft are assumed to have already accumulated an average of 6,000 flying hours and thus are incurring betterment costs. These figures are inflated to the 2017-2018 fiscal year and are not adjusted for risk.

## Model Uncertainty

The use of a regression model approach to costing introduces uncertainty into the cost estimate; that is, the probability that the cost estimates generated by the respective models differ from reality. We therefore explicitly include this class of uncertainty in the final estimates of Operations and Sustainment phase costs given in Section 3.

## Estimating Petroleum, Oil and Lubricant Costs

DND has provided historical data on petroleum, oil and lubricant usage and costs. To calculate total projected costs, we assume that average fuel usage per flying hour is relatively constant over time and establish a yearly usage profile based on the projected number of flying hours (160 per aircraft per year). We then multiply the yearly fuel usage by the most recent yearly average per-litre fuel cost to arrive at a projected petroleum, oil and lubricant cost profile.

### Risk: Petroleum, Oil and Lubricant Price Volatility

Fuel prices are quite volatile, and petroleum, oil and lubricant cost risk represents the single largest risk category in the Operations and Sustainment phase. To capture this risk category, we model potential changes in prices over time based on historical volatility rates and generate a distribution of potential cost outcomes.

### Risk: Inflation

Inflation risk for the “maintenance and munitions” and “betterment” cost categories is modelled exactly as described for the Acquisition phase in Section B.2.

### Sensitivity: Changes in Yearly Flying Rates

Recent history suggests that the CF-18 fleet has an average per-aircraft flying rate of about 160 hours per year. However, this rate is not steady over time, with average flying rates as low as 130 and as high as 190 per aircraft occurring over the last 15 years. These are often influenced by ongoing fleet-wide maintenance and upgrade activities, which are expected to continue to occur over the remaining life of the CF-18 fleet. As such, we include calculations of the cost differences associated with a low rate (-25%) and high rate (+25%) of per-aircraft flying hours.

## B.4 Disposal Phase

**Table B-7** Disposal phase cost elements and risks

| | |
|---|---|
| **Cost Elements:** | Disposal, Demilitarization, Miscellaneous |
| **Risks:** | None |

The Disposal phase occurs at the end of the service life of the additional 18 aircraft. Disposal of these aircraft is carried out in a staggered fashion likely beginning in the 2029-2030 fiscal year and completing by 2032-2033. We have assumed that the aircraft are disposed in the order they are received, with 2 being disposed in 2029-2030, 6 in 2030-2031, 8 in 2031-2032, and 2 in 2032-2033. To calculate the total cost associated with this phase, we use inputs and projections provided by DND on the cost of total CF-18 fleet disposal and attribute costs proportionally to the subset of 18 aircraft. Given DND’s experience in CF-18 aircraft disposal, we consider these costs to be certain, and no additional risk elements are included.

The disposal phase cost estimate ignores the possibility of the resale of any aircraft or components.

# Notes

1. All figures in nominal dollars. Life cycle cost figures rounded to the nearest ten million dollars.
2. To enable comparison, DND's reported $110 M in upgrades and life cycle extension is shifted from the Acquisition phase to the Operations and Sustainment phase. More details on this comparison are available in Section 5.
3. A risk-adjusted cost estimate takes into account financial and project-wide risks that often cannot be mitigated or managed internally.
4. The total CF-18 fleet, as of January 2019, stands at a total of 76 aircraft.
5. Canadian media has reported the total amount to be paid to Australia is $90 million CAD; see, for instance: https://www.cbc.ca/news/politics/australia-f-18-jets-deal-1.4966564
6. Office of the Auditor General of Canada, 2018 Fall Reports to the Auditor General of Canada, Report 3, "Canada's Fighter Force", 2018.
7. This follows standard practice in the Department of National Defence; see, for instance, the KPMG Independent Review of the Life Cycle Costs of Canada's Next Generation Fighter Capability: https://www.canada.ca/en/treasury-board-secretariat/services/reporting-government-spending/what-we-are-doing/next-generation-fighter-capability-independent-review-life-cycle-cost-framework.html
8. Information obtained in discussions with DND officials.
9. Historical betterment and national procurement costs were obtained from: Desmier, P.E., "Forecasting the Operating and Maintenance Costs of Aircraft" in "The Art and Science of Resource Management in the Royal Canadian Air Force". Eds. E.R. Fetterly and B. Solomon. Ottawa: Royal Canadian Air Force Warfare Centre (Forthcoming, 2019).
10. Betterment costs are only available until the 2012-2013 fiscal year.
11. Intermediate maintenance consists of maintenance carried out at on-base maintenance facilities; while material costs associated with these activities are included in the NP budget, labour costs are excluded as they are attributed to base-level operations costs.
12. Department of National Defence, Financial Administration Manual (FAM) Chapter 1020-4, Tangible Capital Assets, 2018.
13. Costs rounded to the nearest $10 million.
14. The selection of these percentiles – the 40$^{th}$ as the low estimate, 50$^{th}$ as most likely, and 80$^{th}$ as the high estimate, is to recognize the tendency for cost overrun to occur in life cycle costing of military systems.

15. The sale of used goods in Australia is subject to applicable Australia taxes; however, taxes can be recuperated if the goods are exported within 60 days of the date of transfer of ownership.

16. Maintenance and munitions costs are modelled using historical National Procurement budget data, which includes the cost of spares, maintenance material, equipment overhaul, munitions, and contracts with foreign governments and private companies for maintenance. It does not include labour associated with intermediate-level maintenance; as such, this figure may be underestimated.

17. Betterment costs are modelled using historical data. The definition of a betterment, according to DND's Financial Administration Manual, is as follows "(a betterment) appreciably improves, enhances of extends the service potential of an existing TCA (Tangible Capital Asset) by meeting at least one of the following criteria: (a) Increasing the capital asset's previously assessed physical output or service capacity; (b) Improving the capital asset's performance and quality of output; (c) Reducing the capital asset's operating costs; or (d) Increasing the useful life of the whole asset by one year or more." Betterment costs therefore fully account for ongoing system improvements and life extension programs.

18. Office of the Auditor General of Canada, 2018 Fall Reports to the Auditor General of Canada, Report 3, "Canada's Fighter Force", 2018.

19. Australian National Audit Office, Audit Report No. 5 2012-13, "Management of Australia's Air Combat Capability – F/A-18 Hornet and Super Hornet Upgrades and Sustainment", 2012.

20. Information on the original safe life specification of the CF-18 is available in: Public Services and Procurement Canada, "Summary Report – Evaluation of Options for the Replacement of the CF-18 Fighter Fleet", December 2014. https://www.tpsgc-pwgsc.gc.ca/app-acq/amd-dp/documents/cf18-eval-eng.pdf

21. The Globe and Mail, "Aging fighter jets a concern for Canada's national defence department", May 27, 2014. https://www.theglobeandmail.com/news/politics/aging-fighter-jets-a-concern-for-canadas-national-defence-department/article18860555/

22. Department of National Defence, Official Response to PBO Information Request IR0385, October 16th, 2018.

23. Information obtained in discussions with DND officials.

24. See, for instance, the Next Generation Fighter Capability Annual Update, 2014. http://www.forces.gc.ca/en/about-reports-pubs/next-gen-fighter-annual-update-2014.page