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The Cost of Canada's Surface Combatants: 2019 Update

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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 updates the 2017 PBO cost estimate of the Government of Canada's procurement of 15 new naval warships.

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Executive Summary

This report provides an updated cost estimate of the Canadian Surface Combatant (CSC) program from the 2017 PBO report, "The Cost of Canada's Surface Combatants."[1] At the time of the previous cost analysis, the government had not yet selected a design for the new generation of warships. This update considers characteristics specific to the Type 26 design chosen by the government while incorporating updated information on the project's timeline.

This updated estimate covers the cost of project development, production, two years of spare parts and ammunition, training, government program management, upgrades to existing facilities, and applicable taxes.

Summary Table 1 displays a breakdown of this report's results. Our estimate of the total cost of the CSC program is $69.8 billion over 26 years, consisting of: $5.3 billion in pre-production costs; $53.2 billion in production costs; and, $11.4 billion in project-wide costs (all in nominal dollars).

In comparison, the 2017 PBO report estimated a total program cost of $61.8 billion, $8 billion less than the updated estimation. The difference in these estimates is due to new information on project specifications provided by the Department of National Defence (DND); in particular, ship construction will begin later (increasing inflation costs), the ship will be larger than assumed in the previous report (increasing real construction costs), and we exclude the cost of spares beyond the initial two years (reducing real program costs).

In 2017, the Government of Canada revised their original 2008 program cost estimate of $26.2 billion[2] to $56-60 billion, with costs to be revisited at the completion of the development phase[3]. There is therefore a difference of $9.8-$13.8 billion between the DND and the updated PBO estimates.

Summary Table 1

Estimated CSC Program cost

$ billions	**2019 PBO**	**2017 PBO**	**DND**
Pre-Production	5.3	5.0	
Production	53.2	38.4	
Project-Wide	11.4	17.9	
Total	69.8	61.8	56-60*

Sources: PBO calculations. Department of National Defence.

Notes: Totals may not add due to rounding. Figures represented in nominal (then-year) dollars.

*DND figures do not include taxes.

Sensitivity analysis indicates that a delay in the start of production of one year, such that the construction of the first ship would begin in 2025, would increase total project costs by almost $2.2 billion.

1. Introduction

This report provides an updated cost estimate for the Canadian Surface Combatant program. In February 2019, the Government of Canada confirmed that Lockheed Martin Canada's bid, based on BAE's Type 26 Global Combat Ship, was selected for the Canadian Surface Combatant program.[4] PBO's previous 2017 cost analysis was based on a generic design and did not account for design characteristics specific to the Type 26, in particular the size of the ship.[5]

Consistent with the 2017 PBO report, this updated estimate covers the cost of project development, production, spare parts, ammunition, training, government program management and upgrades to existing facilities. In this update, we have excluded the cost of spares beyond a two-year initial supply.

The methodology used to produce these estimates is largely unchanged from that which was presented in the 2017 PBO report. The main estimate is produced using a parametric approach with cost estimating relationships calibrated in the PRICE TruePlanning suite of costing software. Estimates derived in this software, in tests against actual program costs, have been shown to be within plus or minus 20 percent.

These results are then compared to cost estimates from two alternative heuristic methods. The first heuristic method measures the factors that increase surface combatant costs for a comparable ship and applies the difference in factors to the Type 26. The second heuristic method benchmarks the ninth ship cost of similar ships to that of the Type 26 (the ninth ship is generally the point at which most efficiencies have been incorporated into the production process and further cost improvements are much smaller).

We also conduct a sensitivity analysis for the effect of delays to the start of construction.

Finally, the findings in this report are compared to those of the 2017 PBO report on the cost estimate of Canada's Surface Combatant program, as well as the most recent cost estimate provided by the Department of National Defence (DND).

1.1. Background

The Canadian Surface Combatant (CSC) program is intended to replace Canada's 12 Halifax-class frigates (also known as the Canadian Patrol Frigate or CPF) and three now-decommissioned Iroquois-class destroyers with a new fleet of 15 warships.[6]

The government's selection of the winning design, BAE Systems' Type 26 Global Combat Ship, was formally announced on 8 February 2019. Lockheed Martin Canada is the design team and Halifax's Irving Shipbuilding Inc. is the project's prime contractor.[7]

The CSC program is currently in the development phase. The government projects the acquisition phase to begin in the early 2020s with deliveries to begin in the mid-2020s. The delivery of the 15th ship, slated for the late 2040s, will conclude the procurement program.[8]

In 2008, the CSC program's original budget was set at $26.2 billion (then-year, or nominal, dollars)[9]. In 2017, the PBO estimated the cost of the CSC program to be almost $62 billion (then-year dollars)[10]. The Government of Canada subsequently revised their cost estimates of the procurement program to a total of $56-60 billion, with costs to be revisited at the completion of the development phase.[11]

1.2. Project Specifications

The Canadian Surface Combatant procurement project has the following stated specifications:

- Based on the Type 26 design by BAE Systems;[12]
- Construction to take place in Halifax, Nova Scotia at Irving Shipbuilding Inc.;[13]
- Procurement of 15 ships to replace 12 Halifax-class frigates and three decommissioned Iroquois-class destroyers;[14]
- A lightship weight of 6,900 metric tons;[15,16] and,
- Construction of the first CSC to begin in early-2020s[17].

1.3. PBO Assumptions

The following are PBO assumptions:

- This costing covers only the Development and Acquisition phases; we do not consider operations and sustainment costs other than a two-year supply of spares and initial ammunition;
- Pre-production activities last approximately six years and end with the beginning of the construction of the first ship;

- Construction begins in FY 2023-2024;
- Production continues until the completion of the 15^{th} ship in 2043-2044;
- Production costs are subject to a learning curve; specifically, subsequent ships in the same production run become cheaper as efficiencies are learned;
- Taxes are included in the cost estimate; and,
- We adopt inflation figures from the PBO's Consumer Price Index Projection in the April 2019 Economic and Fiscal Update[18].

2. Methods

This report largely follows the methodology described in the 2017 PBO report on the cost of Canada’s Surface Combatant program. This section briefly describes the modelling approaches adopted. There are three methodological approaches: one parametric modelling approach which derives the main estimates of this report and two heuristic approaches that are used to confirm the results of the main estimate.

2.1. Parametric Approach

The main estimate in this report is calculated using cost estimating relationships established in the 2017 PBO report. These relationships were developed within the TruePlanning suite of cost estimating software.

What is TruePlanning® and how does it work?

TruePlanning is a proprietary parametric cost estimating model created by PRICE Systems LLC with applications in both military and non-military projects. It has been used by the United States Department of Defense to cost military procurement initiatives as well as many high-profile firms such as BAE and Boeing.

To produce a cost estimate for a given program, the software is first calibrated on the project costs and cost estimating relationships of a comparable historical program; in this case, the Canadian Patrol Frigate program of the 1990s that produced the Halifax-class frigates currently in service. The cost estimating relationships generated by the software are then modified to reflect parameters specific to the new program being costed.

Importantly, we have assessed the assumptions governing the estimates from the 2017 PBO model regarding system complexity, and other factors relevant to costing, as being acceptable for use in the present analysis. Further details on the assumptions and calibration of the TruePlanning model adapted from the 2017 PBO report are available in detail in Appendix B of that report.[19]

2.1.1. Estimating a baseline total project cost

The primary cost estimating relationship in the 2017 PBO report is the relationship between lightship weight and production cost. We use this relationship to derive a total real cost for the project based on the assumptions stated in Sections 1.2 and 1.3, particularly the estimated lightship weight of the Type 26 surface combatant of 6,790 tons and a construction start date in the 2023-2024 fiscal year.

2.1.2. Project cost categories

Once a base real cost is estimated, these costs are distributed among three project phases: Pre-Production, Production, and an overarching Project-Wide category. These categories represent a simplification of the standard lifecycle costing framework used in National Defence projects. In principle, the *Pre-Production* phase roughly translates to the *Development* phase and the *Production* phase translates to the *Acquisition* phase.[20] The *Project-Wide* phase spans both the *Pre-Production* and *Production* phases. The purpose of this simplification is to ensure the timing of project costs is correct and that they are appropriately inflated.

The three project phases contain the following elements:

Pre-Production

- Project development costs, including the purchase of a design and modification to Royal Canadian Navy specifications
- Facility upgrade costs

Production

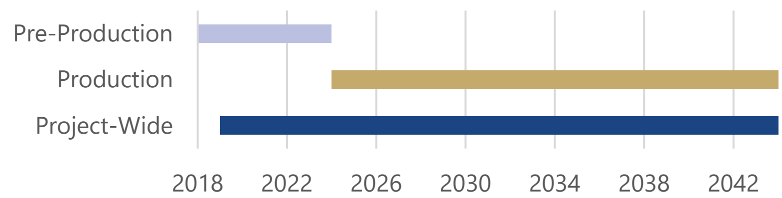
- Total production costs

Project-Wide

- Overhead costs
- Program Management
- Spares and Ammunition
- Training
- Documentation

We then profile the project cost categories over the project's duration. As seen in Figure 2-1, the *Pre-Production* phase, assumed to have begun in the 2018 fiscal year (FY), continues until the start of the *Production* phase in FY 2024. The *Production* phase has a duration of 20 years, ending with the delivery of the final ship in FY 2044. The *Project-Wide* phase has a duration of 25 years, ending in FY 2044 while spanning the entirety of the *Production* phase and the majority of the *Pre-Production* phase.

Figure 2-1 Timeline of project cost categories



Source: PBO

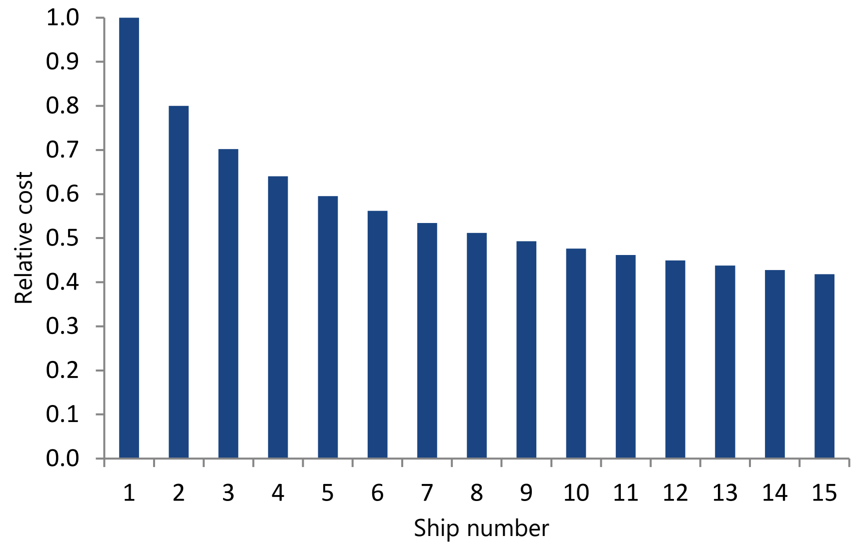
2.1.3. Timing of costs within categories

For the purposes of this analysis, we assume that the timing of costs within the *Pre-Production* and *Project-Wide* cost categories is evenly distributed throughout their respective timeframes. For example, if our estimate for the total of the six-year span of the *Pre-Production* phase is $6 billion (in real terms), our model assumes that each year incurs a cost of $1 billion for the associated project activities.

The *Production* cost category implements a learning curve to distribute costs across the production run. This reflects the fact that shipyards generally become more efficient at building ships of the same class over a given production run; the second ship is cheaper than the first, and the third is cheaper than the second, and so forth. Research into learning curves in naval shipbuilding has shown that most efficiencies are gained prior to the ninth ship in the production run, with only marginal improvement coming afterwards.[21]

An example of a distribution of ship costs within a production run assuming an 80 percent learning curve is given in Figure 2-2. An 80 percent learning curve indicates that for every doubling in quantity of units produced, costs are reduced to 80 percent; the second ship produced has a cost that is 80 percent of the first; the fourth ship's production cost is 80 percent of the second, and so forth. The timing of costs within the production category is therefore more heavily weighted towards the start of production.

Figure 2-2 Illustration of an 80 percent learning curve



Source: PBO

The 2017 PBO report had assumed a learning curve rate of approximately 77.5 percent, based on historical data on naval shipbuilding in Canada; we maintain this assumption from our previous study.

2.1.4. Arriving at a final estimate

The costs for each category are summed across each year in the program and escalated according to (1) the PBO's Consumer Price Index projections[22] and (2) a defence-specific inflation premium. This latter category of inflation accounts for the gap between historical economic inflation and the inflation observed in the naval shipbuilding industry. Research by the Congressional Budget Office has shown that prices in naval shipbuilding increase by an additional 1.2 percent per year on average.[23]

After the inflation factors are applied, we calculate total (then-year) project costs by summing across all years of the program.

3. Alternative Heuristics

Two alternative heuristic methods are used to validate the estimation from the main parametric approach. Both heuristic methods follow those in the 2017 PBO report.[24] The alternative methods are based on heuristics in other research: the 2006 RAND paper "Why Has the Cost of Navy Ships Risen?" and the 2015 RAND paper "Australia's Naval Shipbuilding Enterprise". [25, 26]

3.1. First Heuristic Method

The first heuristic methodology measures the factors that increase surface combatant costs for the Canadian Patrol Frigate (CPF) and applies the difference in factors to the Type 26. This methodology is based on the heuristics detailed in the 2006 RAND paper "Why Has the Cost of Navy Ships Risen?". [27]

This heuristic estimation method has the following steps:

Why use a ninth ship cost?

Using the cost of the ninth ship allows for more accurate cost comparisons. In general, by the ninth ship, the shipyard has finished going through the steeper part of the learning curve and further cost improvements are much smaller. So, comparing ninth ships is more accurate since the near minimum costs for both shipyards have been reached.

1. Beginning with the cost of the ninth CPF program ship, we deflate the cost by 1.2 percentage points above inflation per year[28], from the date of delivery in FY 1994 to the beginning of deliveries in FY 1991.

2. We then inflate to FY 2004 by two percent to account for non-obvious capability improvements, such as improved materials and technological progress in electronics. This cost increase occurs in the period between the delivery of the first ships in the comparing classes. The RAND dataset only covers a 40-year period ending in 2004 and it is uncertain if this increase continued after 2004. To be cautious, the two percent inflation is only applied until the end of the RAND report coverage, rather than the first expected delivery date of the Type 26.

3. Next, we account for inflation and defence specific inflation observed between programs. We inflate the cost 1.5 percentage points above inflation from FY 1991 to FY 2017. Of the 1.5 percentage points, 0.4 percentage points account for economy driven, inter-generation inflation and 1.1 percentage points account for power density specific inflation to reflect changes in system complexity.[29, 30]

4. The cost is then adjusted to account for weight differences between the CPF and Type 26. The Type 26's design states a lightship weight of 6,790 tons, an 81 percent increase over the CPF's lightship weight

of 3,748 tons[31]. Therefore, the cost is multiplied by approximately 1.81.

5. The final step is to consider the tax differences of where the CPF and Type 26 are built. The effective tax rate for the CPF project was 6.1 percent.[32] The Type 26 will be built in Nova Scotia, which has a current HST tax rate of 15 percent.[33] The 8.9 percent differential is used to increase the cost of the ship to reflect these differences in tax rates.

3.2. Second Heuristic Method

The second heuristic methodology follows a benchmarking approach suggested in the 2015 RAND paper "Australia's Naval Shipbuilding Enterprise".[34] This approach consists of basing the cost estimate of a new ship on those of comparable ships within the same class and generation while adjusting for differences in lightship weight and wage rates.

For the purpose of this benchmarking approach, we select three comparable surface combatant programs: France's FREMM multipurpose frigate, Norway's Fridtjof Nansen frigate, and the United States' Arleigh Burke destroyer. The ninth ship cost for the FREMM and Fridtjof Nansen programs are estimated based on average ship costs for these programs; the Arleigh Burke ninth ship cost is obtained from US Navy budget submissions.[35]

1. First, the unit costs for each class of ship are inflated to FY 2017 using economic and defence-specific inflation.[36] The cost is converted to Canadian dollars from its original currency and adjusted to reflect the difference in lightship weight of the ships.

2. Since the benchmark ships were built outside of Canada, we adjust the costs to account for differences in labour rates; for this purpose, we obtain average hourly rates for shipbuilding-related occupations for each of the three countries and convert these to Canadian dollars. [37] After this, we adjust the labour component, roughly 31.4 percent of the total ninth ship cost, accordingly.

3. Finally, the FREMM and Fridtjof Nansen average ship costs must be adjusted to reflect the ninth ship cost. Based on the available shipbuilding cost data from the 2017 PBO report, we estimate that the ninth ship cost is slightly cheaper than the average ship cost for a given program; ninth ship costs are approximately 96 percent that of the average ship costs. Therefore, we multiply the average ship unit cost by 96 percent to calculate the cost of the ninth ship.

Remaining agnostic with regards to the comparability of the Type 26 to each of the three ship classes, we take the average of the three ninth ship costs calculated in this heuristic to arrive at an estimate.

4. Results

In this section we report the results of the three different methodologies used: the main parametric approach and the two heuristic approaches.

4.1. Parametric Approach

Table 4-1 shows the results for the main estimates using the parametric approach. The estimated total production cost is $69.8 billion (then-year, or nominal, dollars). Pre-production costs account for $5.3 billion, about eight percent of total costs. Over 76 percent of the total cost stems from production, totalling approximately $53.2 billion. Project-wide costs make up about 16 percent of the total cost, at $11.4 billion.

Table 4-1

Estimated CSC Program cost

$ billions	**2019 PBO**
Pre-Production	5.3
Production	53.2
Project-Wide	11.4
Total	69.8

Source: PBO calculations.

Notes: Totals may not add due to rounding. Figures represented in nominal (then-year) dollars.

4.2. Alternative Heuristics

Table 4-2 displays the results for the alternative heuristics along with individual comparisons to the three ships used in the second heuristic method.

As shown in Table 4-2, the first heuristic produces a ninth ship cost estimate of $2.1 billion (FY 2017). Compared to the main estimate of $1.9 billion from the parametric approach, this estimate is about 10 percent higher.

The second heuristic produces an average ninth ship cost estimate of $1.8 billion (FY 2017). Compared to the main estimate, $1.9 billion, this estimate is about 8 percent lower.

The second heuristic uses an average of three ships: France's FREMM multipurpose frigate, Norway's Fridtjof Nansen frigate, and the United States' Arleigh Burke destroyer. Comparing the ships individually to the ninth ship cost of the CSC, the FREMM produces an estimate about 19 percent cheaper, the estimate of the Fridtjof Nansen is 7 percent cheaper, and the Arleigh Burke is approximately one percent more expensive.

Table 4-2

Estimated Cost of the Ninth Ship

$ billions		**Ninth Ship Cost**	**Difference**
Parametric		**1.9**	
Heuristic 1		**2.1**	**10.4%**
Heuristic 2	*FREMM*	*1.6*	*-19.4%*
	Nansen	*1.8*	*-6.9%*
	Arleigh	*2.0*	*1.1%*
	Average	**1.8**	**-8.4%**

Source: PBO calculations.

Notes: Figures in FY 2017. Numbers may not add due to rounding

5. Sensitivity Analysis

We conduct a sensitivity analysis on the main parametric approach to determine the additional cost of a one-year and a two-year delay in the start of construction. We assume that any delays will occur during the pre-production phase; thus, the pre-production phase will be lengthened, while the production phase is pushed back by the length of the delay. Our model assumes that any additional costs from these delays are due to inflation.

As described in Section 2.1, the pre-production, production, and project-wide phases span six, 20, and 25 years, respectively. A one-year delay will extend the pre-production phase by one year to a total of seven years, ending in FY 2024. The production and project-wide phases will remain the same length in time but will begin one year later. The production phase would start in FY 2025 and end FY 2045, while the project-wide phase would begin incurring costs in FY 2020 and continuing until FY 2044. The same approach is used for a two-year delay.

Table 5-1 presents the results of the sensitivity analysis. A one-year delay would increase the total program cost by almost $2.2 billion, a three percent increase, while a two-year delay would increase the total cost by almost $4.5 billion, representing a six percent increase.

Table 5-1 Estimated CSC Program cost with delays

$ billions	Total Program Cost	$ Increase	% Increase
On-time	69.8		
1-year delay	72.0	2.2	3.1%
2-year delay	74.3	4.5	6.0%

Source: PBO calculations.

Notes: In nominal dollars. Numbers may not add due to rounding.

6. Comparison to Previous Estimates

This section compares the updated cost estimate of the CSC program to the estimates and assumptions from the 2017 PBO report. The results are also compared to the Department of National Defence's most recent estimate of the CSC program.

Table 6-1 presents the comparison of these estimates. The updated total program cost, $69.8 billion, is about $8 billion higher than the 2017 PBO report estimate of $61.8 billion.

A key cost driver is the weight of the ship. Ship displacement represents the primary factor in the model's cost estimating relationships. The 2017 PBO report estimates project costs based on a 5,400 ton lightship weight, which was an estimate based on available designs for the CSC project at the time. With the announced selection of the Type 26 design, we now know the lightship weight of the design to be 6,790 tons, a significant increase.

A second significant factor in the increase in the PBO cost estimate is attributable to the change in the CSC project timeline assumptions. We now assume that the project's construction phase will begin a full three years later than first assumed in the 2017 PBO study; this affects the start and duration of the project's development phase while pushing back the start of the project's construction phase.

Delays in acquisition of material will result in higher nominal costs because of inflation. Moreover, as noted earlier, research indicates that there is a defence-specific inflation premium that will also result in further nominal cost escalation.

Finally, the current estimate does not include the cost of spares beyond an initial two-year supply. Removing the additional spares mitigates the total increase in estimated program cost.

The DND's initial cost estimate in the 2008 Budget set the cost of the CSC program at $26.2 billion.[38] In 2017, the department revised their estimate to $56-60 billion[39], approximately $9.8 billion to $13.8 billion lower than our current estimate of $69.8 billion. DND has not yet published a detailed breakdown of estimated project costs; we are thus unable to provide a disaggregated comparison.

Table 6-1 Estimated CSC Program cost

$ billions	**2019 PBO**	**2017 PBO**	**DND**
Pre-Production	5.3	5.0	
Production	53.2	38.4	
Project-Wide	11.4	17.9	
Total	69.8	61.8	56-60*

Sources: PBO calculations. Department of National Defence.

Notes: Totals may not add due to rounding. Figures represented in nominal (then-year) dollars.

*DND figures do not include taxes.

A comparison of revised and previous PBO heuristic estimates is presented in Annex A.

Appendix A: Comparison to Previous Estimates: Alternative Heuristics

In this section, we compare the results of the two alternative heuristics to those of the 2017 PBO report.

Methodological changes

While the heuristic methods are largely the same as those used in the previous report, a few changes were effected in order to improve the fidelity of the estimates:

- The heuristic methods in this report use historical inflation data rather than an assumed two percent per year.
- In the first heuristic method, we use a 1.1 percent rate of defence-specific inflation to account for differences in power density between generations of ships[40], whereas the 2017 report used a ratio of kilowatts per ton between ship generations.
- In the second heuristic method, we use three ships for the purposes of benchmarking rather than one.

Comparison of heuristic results

Table A-1 presents a comparison of the heuristic results between the present analysis and that of the 2017 PBO report.

As discussed in Section 4.2, the first heuristic is about 10 percent higher than the estimate from the parametric approach. In the 2017 PBO report, there was a similar finding for the first heuristic: the estimate was 13 percent higher than its parametric approach.

The second heuristic produces an average estimate about eight percent lower than the estimate from the parametric approach. The 2017 PBO report of the second heuristic produced an estimate three percent higher than its parametric approach. The second heuristic in the 2017 PBO report, however, is based solely on the American Arleigh Burke. As seen in Section 4.2 and in Table A-1, the Arleigh Burke estimate is about one percent higher than the parametric estimate, similar to the 2017 PBO results.

Table A-1 Comparison of Estimated Ninth Ship Costs

$ billions			Ninth Ship Cost	Difference
2019 PBO	Parametric		**1.9**	
	Heuristic 1		**2.1**	**10.4%**
	Heuristic 2	*FREMM*	*1.6*	*-19.4%*
		Nansen	*1.8*	*-6.9%*
		Arleigh	*2.0*	*1.1%*
		Average	**1.8**	**-8.4%**
2017 PBO	Parametric		**1.6**	
	Heuristic 1		**1.8**	**13.2%**
	Heuristic 2	*Arleigh*	**1.6**	**3.1%**

Source: PBO calculations.

Notes: Figures in FY 2017. Numbers may not add due to rounding.

Notes

1. Parliamentary Budget Officer. (2017). The Cost of Canada's Surface Combatants.
2. Public Services and Procurement Canada. (2019). Shipbuilding project to equip the royal Canadian Navy and the Canadian Coast Guard, from https://www.tpsgc-pwgsc.gc.ca/app-acq/amd-dp/mer-sea/sncn-nss/projets-projects-eng.html
3. Department of National Defence. (18 April 2019). Canadian surface combatant, from https://www.canada.ca/en/department-national-defence/services/procurement/canadian-surface-combatant.html
4. Department of National Defence. (18 April 2019). Canadian surface combatant, from https://www.canada.ca/en/department-national-defence/services/procurement/canadian-surface-combatant.html
5. Parliamentary Budget Officer. (2017). The Cost of Canada's Surface Combatants.
6. Department of National Defence. (18 April 2019). Canadian surface combatant, from https://www.canada.ca/en/department-national-defence/services/procurement/canadian-surface-combatant.html
7. Department of National Defence. (18 April 2019). Canadian surface combatant, from https://www.canada.ca/en/department-national-defence/services/procurement/canadian-surface-combatant.html
8. Department of National Defence. (18 April 2019). Canadian surface combatant, from https://www.canada.ca/en/department-national-defence/services/procurement/canadian-surface-combatant.html
9. Public Services and Procurement Canada. (2019). Shipbuilding project to equip the royal Canadian Navy and the Canadian Coast Guard, from https://www.tpsgc-pwgsc.gc.ca/app-acq/amd-dp/mer-sea/sncn-nss/projets-projects-eng.html
10. Parliamentary Budget Officer. (2017). The Cost of Canada's Surface Combatants.
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13. Public Services and Procurement Canada. (2019). Shipbuilding project to equip the royal Canadian Navy and the Canadian Coast Guard, from https://www.tpsgc-pwgsc.gc.ca/app-acq/amd-dp/mer-sea/sncn-nss/projets-projects-eng.html

14. Public Services and Procurement Canada. (2019). Shipbuilding project to equip the royal Canadian Navy and the Canadian Coast Guard, from https://www.tpsgc-pwgsc.gc.ca/app-acq/amd-dp/mer-sea/sncn-nss/projets-projects-eng.html

15. BAE Systems. (2019). Global Combat Ship, from https://www.baesystems.com/en-uk/product/global-combat-ship

16. This is approximately 6,790 long tons, the metric used for this report.

17. Department of National Defence. (18 April 2019). Canadian surface combatant, from https://www.canada.ca/en/department-national-defence/services/procurement/canadian-surface-combatant.html

18. Parliamentary Budget Officer. (2019). Economic and Fiscal Outlook: April 2019.

19. Parliamentary Budget Officer. (2017). The Cost of Canada's Surface Combatants, Appendix B.

20. The project management cycle used by the Department of National Defence includes the Development, Acquisition, Operations and Sustainment, and Disposal phases; see, for instance the Next Generation Fighter Capability Annual Update, 2014. https://www.canada.ca/en/department-national-defence/corporate/reports-publications/equipment/next-generation-fighter-capability-annual-update-2014.html

21. Arena, M.V., Blickstein, I., Younossi, O., and Grammich, C.. (2006). Why Has The Cost of Navy Ships Risen? RAND Corporation.

22. Parliamentary Budget Officer. (2019). Economic and Fiscal Outlook: April 2019.

23. Congressional Budget Office. (2017). An Analysis of the Navy's Fiscal Year 2017 Shipbuilding Plans. https://www.cbo.gov/sites/default/files/115th-congress-2017-2018/reports/52324-shipbuildingreport.pdf

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25. Arena, M.V., Blickstein, I., Younossi, O., and Grammich, C.. (2006). Why Has The Cost of Navy Ships Risen? RAND Corporation.

26. Birkler, J., Schank, J. F., Arena, M. V., Keating, E. G., Predo, J. B., Black, J., . . . Younossi, O. (2015). Australia's Naval Shipbuilding Enterprise. Santa Monica, California: RAND Corporation.

27. Arena, M.V., Blickstein, I., Younossi, O., and Grammich, C.. (2006). Why Has The Cost of Navy Ships Risen? RAND Corporation.

28. The United States Congressional Budget Office found that the cost of naval construction increases at a rate of 1.2 percent above the GDP inflation rate. Congressional Budget Office (2017).

29. Arena, M.V., Blickstein, I., Younossi, O., and Grammich, C.. (2006). Why Has The Cost of Navy Ships Risen? RAND Corporation.

30. Defence specific inflation is comprised of two parts in this step: economy-driven specific and power density specific. Economy-driven inflation is the amount in which shipbuilding inflates faster than CPI inflation to account for differences in labour, equipment, and material. Power density inflation accounts for differences in technology complexity.

31. Parliamentary Budget Officer. (2017). The Cost of Canada's Surface Combatants.

32. When the CPF project started, Canada had a Manufacturers' Sales Tax (MST) which was replaced by the General Sales Tax (GST) in 1991, part way through the CPF project. Since there was not a consistent tax rate in place through the CPF program, the effective tax rate for the program was estimated using the Canadian Patrol Frigate Project Completion Report. In the CPF Project Completion Report, there is a total Federal Sales Tax (FST), another name for MST or GST, of approximately $323 million and the total contractor ceiling price of approximately $5,299 million, giving an effective tax rate of 6.1 percent. National Defence. (2005). Canadian Patrol Frigate Project Completion Report.

33. Canada Revenue Agency. (28 September 2016). GST/HST provincial rates table, from http://www.cra-arc.gc.ca/tx/bsnss/tpcs/gst-tps/rts-eng.html.

34. Birkler, J., Schank, J. F., Arena, M. V., Keating, E. G., Predo, J. B., Black, J., . . . Younossi, O. (2015). Australia's Naval Shipbuilding Enterprise (pp. 294). Santa Monica, California: RAND Corporation.

35. Cost estimate of the ninth Arleigh Burke at each of the US shipyards estimated by PBO using cost data from the Department of the Navy (2016). Department of the Navy. (2016). Shipbuilding and Conversion, Navy Department of Defense Fiscal Year (FY) 2017 President's Budget Submission.

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37. Economic Research Institute (2019).

38. Public Services and Procurement Canada. (2019). Shipbuilding project to equip the royal Canadian Navy and the Canadian Coast Guard, from https://www.tpsgc-pwgsc.gc.ca/app-acq/amd-dp/mer-sea/sncn-nss/projets-projects-eng.html

39. Department of National Defence. (18 April 2019). Canadian surface combatant, from https://www.canada.ca/en/department-national-defence/services/procurement/canadian-surface-combatant.html

40. Arena, M.V., Blickstein, I., Younossi, O., and Grammich, C.. (2006). Why Has The Cost of Navy Ships Risen? RAND Corporation.