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THE COST OF CANADA'S SURFACE COMBATANTS: 2021 UPDATE AND OPTIONS ANALYSIS

OFFICE OF THE PARLIAMENTARY BUDGET OFFICER
BUREAU DU DIRECTEUR PARLEMENTAIRE DU BUDGET

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.

In response to a request by the House of Commons Standing Committee on Government Operations and Estimates (OGGO), this report presents a costing analysis of building Canadian Surface Combatants (CSC) with the continuation of the Type 26, as well as the cost for two alternate designs: the FREMM and the Type 31e.

The authors would like to thank Dr. Eric J. Labs from the United States Congressional Budget Office for his valuable insight and commentary on this research. The authors are grateful to the Congressional Budget Office for their assistance in obtaining cost data on the Arleigh Burke-class Flight IIA destroyer. As well, the authors are thankful to Professor Scott Orr of the UBC Sauder School of Business for his insight into international unit labour cost comparisons.

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Executive Summary

On June 19, 2020 the House of Commons Standing Committee on Government Operations and Estimates (OGGO) requested that the Office of the Parliamentary Budget Officer (PBO) undertake a costing analysis of the Canadian Surface Combatant (CSC) project. This was to include the cost of the current program, based on the Type 26 design, as well as the cost for two other designs: the FREMM and the Type 31e.[1]

In response to this request, this report presents PBO's updated estimates for the current Type 26-based CSC program as well as estimates for notional procurement programs based on the two alternate designs. These cost estimates are inclusive of all activities associated with the development and acquisition phases of the procurement project and also account for provincial taxes and an initial 2-year supply of spare parts for each vessel. They do not include operating costs for the lifespan of the vessels.

The cost estimates for the alternate designs reflect two scenarios under which the FREMM or the Type 31e could be procured. Scenario 1 assumes the CSC program would be reset in favour of a new design for all 15 ships, incorporating cancellation costs and a four-year delay; scenario 2 assumes a hybrid approach under which three Type 26 vessels are procured and the remaining 12 ships are competed, with either the FREMM or Type 31e being selected.

It is important to note there are differences in capabilities when comparing the cost of these three designs. The Canadian Type 26 design is intended to replace the capabilities of the Halifax-class frigate and the Iroquois-class destroyer. That is, it will be relatively large, will be able to conduct air, surface, sub-surface and information warfare missions simultaneously, and operate independently or as part of a larger formation.[2] According to the Department of National Defence (DND), its mission profile will be diverse and the ships will be capable of supporting Canadian and allied armed forces ashore, conducting counter-piracy, counter-terrorism, interdiction and embargo operations for medium intensity operations; and delivering humanitarian aid, search and rescue, law and sovereignty enforcement for regional engagements.[3]

For our estimated costs of a CSC program based on the FREMM design, we tailor our estimates to the specifications of the United States Constellation-class frigate, the newest variant of the FREMM. It is a general-purpose frigate with the ability to conduct anti-air, anti-surface, anti-submarine, and electronic warfare, either independently or as part of a larger formation. Compared to larger, more capable vessels such as modern destroyers and

cruisers, the ship's area-defence anti-aircraft warfare capabilities may be more limited, extending to a lesser range.[4]

The Type 31e design estimated in this report is a planned class of general-purpose frigates for the United Kingdom's Royal Navy. It was intended to be lighter and have more modest capabilities than the Type 26.[5] Furthermore, this specific variant was designed to operate alongside the "higher-end" Type 26.[6]

We estimate that a fleet of 15 Type 26 ships will cost $77.3 billion, rising to $79.7 billion if there is a one-year delay in the start of construction and $82.1 billion if there is a two-year delay. The cost of 15 FREMM ships is estimated at $71.1 billion, inclusive of cancellation costs, running a new competitive design selection process, and a four-year delay, while a fleet of 15 Type 31e ships is estimated at $27.5 billion. The cost for a mixed fleet of the Type 26 ships and the alternate designs increases to $71.9 billion and $37.5 billion, respectively (three Type 26 ships and 12 of either FREMM or Type 31e ships).

Summary Table 1 CSC Costs for the Type 26 and alternate designs

$ billions	Type 26	FREMM		Type 31e	
		Scenario 1	Scenario 2	Scenario 1	Scenario 2
Development	4.4	3.7	3.7	1.8	1.8
Acquisition*	72.9	65.5	51.0	23.8	18.5
Other	n/a	1.9**	17.2†	1.9**	17.2†
Total	**77.3**	**71.1°**	**71.9**	**27.5°**	**37.5**

Sources: PBO Calculations, Department of National Defence, Odense Maritime, Babcock International, Congressional Budget Office

Notes: Figures are in nominal dollars.
* Includes 2-year supply of spares.
** Design change and sunk costs.
† Type 26 development and acquisition costs for first 3 ships.
° Includes calculated cost of delaying the CSC program by 4 additional years.

Our Type 26 cost estimate is an increase of 11 per cent from our 2019 estimate due to updates in specifications and timelines. These are explained in Appendix A:.

Our cost estimates are inclusive of a 10 per cent provincial sales tax.

1. Introduction

On June 19, 2020 the House of Commons Standing Committee on Government Operations and Estimates (OGGO) requested that the Office of the Parliamentary Budget Office (PBO) undertake a costing analysis of the Canadian Surface Combatant (CSC) project. This was to include the cost of the current program – the Type 26 – as well as the cost for two other designs: the FREMM and the Type 31e.[7]

In response to this request, this report presents PBO's updated estimates for the current Type 26-based CSC program as well as estimates for notional procurement programs based on the two alternate designs. These cost estimates are inclusive of all activities associated with the development and acquisition phases of the procurement project and also account for provincial taxes and an initial 2-year supply of spare parts for each vessel.

The estimates for the current CSC program are updated to reflect new ship specifications and timeline assumptions. 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. Compared to the 2019 PBO report, we have undertaken extensive updates to our in-house model to allow for additional granularity in the estimation of Cost Estimating Relationships (CERs) used to produce our estimates.[8]

Estimates for both the FREMM and Type 31e are calculated using an "analogue" approach similar to that which was employed in the 2020 PBO report on Canada's Joint Support Ships (JSS).[9] This approach calculates an average cost per metric tonne for a comparator ship (the analogue ship) and then implements a series of adjustments to account for differences between the analogue and the design for which costs are being estimated and taking into account differences in productivity between nations, exchange rates, and cost escalation rates. The FREMM estimates use the United States Navy's Arleigh Burke-class Flight IIA as a comparator, while the estimates for the Type 31e are based on Denmark's Iver Huitfeldt design.

This report also provides a brief overview of the respective capabilities of each of the three designs. This is done primarily to contextualize the estimates for each platform and is not intended as an authoritative or exhaustive assessment.

Box 1: Specifications of Ship Designs

	Type 26	**FREMM**	**Type 31e**
LSW	7,800	6,111	4,900
Beam	20.75m	19.7m	19.8m
Max speed	27 knots	30 knots	28 knots
Propulsion	CODLOG	CODLAG	CODAD
Crew	204	200	187

Sources: DND, CBO, Babcock International
Notes: CODLOG: combined diesel electric or gas
CODLAG: combined diesel electric and gas
CODAD: combined diesel and diesel

2. Updated CSC Estimates

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.

The Canadian Surface Combatant is intended to replace both the current fleet of Halifax-class frigates and three decommissioned Iroquois-class destroyers with a new fleet of 15 warships. Compared to other ships of its class, the Type 26-based CSC will be relatively large with an anticipated lightship weight of 7,800 metric tonnes and a length of just over 151 metres.

The CSC program is currently in the development phase. The government projects the acquisition phase to begin in 2023-24 with deliveries to begin in the 2030-31.[10] The delivery of the 15th ship, which PBO estimates to be in 2044-45, will conclude the procurement program.[11]

In 2008, the original budget was set at $26.2 billion (then-year, or nominal, dollars).[12] In 2017, the PBO estimated the cost of the Type 26 ships to be almost $62 billion (then-year dollars).[13] 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.[14] In 2019, PBO updated its cost estimate of the Type 26 to $69.8 billion (then-year dollars).

2.1. Data and Methodology

The 2019 PBO model is updated to reflect recent changes in the CSC program concerning ship characteristics and project timelines and assumptions. [15] In addition, we effect a series of updates to the model itself to incorporate more granularity in the cost estimating relationships (see Appendix A). Highlights of the changes to the model include:

- Updated cost estimating relationships (CER) to allow for more granularity;
- Updated assumptions on development and ancillary acquisition costs;
- Adjustments to the assumed learning curve to reflect new project assumptions and a stricter definition of applicable cost categories;

- A narrower definition of applicable taxes, removing recoverable federal taxes from calculations; and,
- Updates to PBO projections for Consumer Price Index (CPI) and shipbuilding inflation.

This report independently estimates the cost of the development and acquisition phases. Cost elements within these categories include design, project management, production, ammunition, infrastructure and facilities, training and testing, and a two-year supply of spare parts.

As in the 2019 report, the main estimate is produced using a parametric approach with cost estimating relationships calibrated in the PRICE TruePlanning suite of costing software. Our estimates are calculated according to the latest schedule provided by DND; however, we also calculate a sensitivity whereby we assume a 1-year and 2-year delay beginning in 2021-22.

2.2. Results

The estimated total cost of production for the Type 26 fleet is $77.3 billion in nominal dollars. Table 2-1 presents the cost separated into the design and acquisition phases of the procurement project. Construction costs, which are a component of total acquisition costs, represent the majority at roughly 76 per cent or $58.6 billion.

Table 2-1 Total procurement cost of Type 26, by component

	Point Estimate	1-year delay	2-year delay
Development	4.4	4.5	4.5
Acquisition - Production	58.6	60.5	62.4
Ancillary acquisition	13.0	13.4	13.8
Spares	1.3	1.4	1.4
Total	**77.3**	**79.7**	**82.1**

Sources: PBO Calculations, Department of National Defence.
Notes: Spares are for two years.
Figures are in nominal (then-year) dollars.
Figures may not sum due to rounding.
Both the 1-year and 2-year delay are assumed to begin in 2021-22.
Ancillary acquisition costs include facilities and infrastructure, acquisition project management, ammunition, training and testing.
Development includes design and project management.

Assuming a one-year delay that results in a delay of all subsequent production and begins in the 2021-22 fiscal year, PBO estimates increased costs of $2.3 billion. This increases to $4.8 billion if the delay is two years long. This assumption extends the delivery of every subsequent ship by one to two years with delivery of the final ship in 2045-46 or 2046-47.

Our cost estimate of the CSC program has increased by 11% since our 2019 report. This is due to a combination factors including a significant increase in lightship weight (from 6,900 to 7,800 tonnes) and a shift in the start of construction; these factors and others are explained in greater detail in Appendix A.

Table 2-2 Cost estimate comparison of production of the Type 26

	PBO 2021	PBO 2019	DND
Acquisition - Production	58.6	53.2	
Other	18.7	16.6	
Total	**77.3**	**69.8**	**56-60***

Sources: PBO calculations, Department of National Defence
Notes: Figures are in nominal (then-year) dollars.
*DND figures do not include taxes.

3. Alternate Designs

As part of the motion passed by the House of Commons Government Operations and Estimates committee that prompted this report, the committee requested estimates of the cost of building two alternate designs for the Canadian Surface Combatant program: the FREMM European multi-mission frigate[16] and the Type 31e.

3.1. Design Characteristics

A detailed analysis of the **capabilities** of the FREMM or the Type 31e with respect to those of the Type 26 **is outside the scope of this report**. In the interests of transparency and properly contextualizing the fiscal analysis of the hypothetical procurement of these alternate designs, we briefly describe the general characteristics of these designs. These descriptions are not to be interpreted as an evaluation of the military effectiveness of these designs nor an assessment of their fitness for the Royal Canadian Navy.

In our analysis, we estimate costs associated with design work that would be necessary to modify the existing designs to Canadian standards and the needs identified by the Royal Canadian Navy. These costs should be interpreted as being conditional on the specifications and limitations of the design in question and not as an estimate of the expenditures that would be required to render the designs equivalent in terms of capabilities.

Further, we note that both the FREMM and the Type 31e are designed for modularity and through-life capacity for the upgrading of capabilities. These aspects are not considered in this section.

FREMM

The FREMM is a multi-purpose frigate currently in service with the French and Italian navies, with export customers Egypt and Morocco also currently operating one vessel apiece. The United States also recently announced that its next generation of frigates, the Constellation-class, will be based on the FREMM design. Compared to other vessels of its class, the FREMM is relatively large, with lengths varying between 132.5 to 151 metres, and full-load displacements varying between 6,000 and 7,400 tonnes. [17] Displacement varies according to the role of the ship; i.e., whether it is primarily outfitted for an anti-aircraft, anti-submarine, or general purpose role.

For the purposes of this analysis, we tailor our estimates to reflect the specifications of the United States Constellation-class frigate. The US Navy intends the Constellation-class to be a general-purpose frigate with the ability to conduct anti-air, anti-surface, anti-submarine, and electronic warfare, either independently or as part of a larger formation. Compared to larger, more capable vessels such as modern destroyers and cruisers, the ship's area-defence anti-aircraft warfare capabilities may be more limited, extending to a lesser range.[18]

Type 31e

The Type 31e is a planned class of general-purpose frigates for the United Kingdom's Royal Navy. While the Type 26 design was initially selected to replace all 13 of the Royal Navy's aging Type 23-class frigates, cost and schedule pressures resulted in the quantity to be reduced to 8, with the remaining requirement for 5 vessels to be subjected to a new competition aimed at delivering a more cost-effective alternative. The Type 31e was therefore intended to be lighter and have more modest capabilities compared to the Type 26.[19] The UK Ministry of Defence has since selected Babcock International's Arrowhead 140 design, which is itself based on Denmark's Iver Huitfeldt-class frigate, as the design for the Type 31e class.[20]

With a planned lightship weight of approximately 4,900 tonnes, the Type 31e is significantly lighter than the US variant of the FREMM (6,110 tonnes) and the planned Type 26 (7,800 tonnes). Slated to fill a role as a light frigate alongside the Royal Navy's "higher-end" Type 26,[21] the Type 31e is expected to be capable of engaging in offensive and defensive surface, air, anti-submarine, and electronic warfare, independently or as part of a larger formation.[22]

3.2. Scenarios and Costing Assumptions

To better inform parliamentarians of the potential set of approaches for a CSC program based on alternate designs, we develop two scenarios under which the FREMM or the Type 31e could be procured. Scenario 1 assumes the CSC program would be reset in favour of the selection of a new design for all 15 ships, incorporating cancellation costs and a four-year delay; Scenario 2 assumes a hybrid approach under which three Type 26 vessels are procured and the remaining 12 ships are competed, with either the FREMM or Type 31e being selected as the winning design.

Common Assumptions, Scenarios 1 and 2

The following assumptions are common to both procurement scenarios:

- We assume there are no changes to the industrial strategy adopted for the CSC program; that is, shipyard, industry engagement, domestic content, etc.;
- Compared to the competitive process that selected the Type 26, we assume a shortened time frame for the selection of a new design, completed within two years, with total real costs remaining the same;
- The costs of design purchase, reconciliation, and other activities relating to design work are proportional to the estimated construction costs of the alternative designs;
- The real expenditure profiles for the acquisition phase, on a percentage basis, are identical to those of the Type 26-based CSC program, with assumed project delays for alternative designs acting as an offset to these profiles;[23] and,
- Ancillary acquisition costs such as project management activities are proportional to construction costs.

Scenario 1 - Alternate Design for All 15 Ships

In the first scenario, we assume that a decision is taken by the Government to cease the Type 26-based procurement project in favour of a new competitive process. Costs associated with the program would continue to be incurred until midway through the 2021-22 Fiscal Year (1 October 2021), at which point a new development phase would begin.

The development phase includes a full competitive process assuming only minor changes to the original Request for Proposal (RFP), with a shortened time frame for a new design to be selected (approximately 2 years). To reach a state of maturity comparable to that of the Type 26 design, we assume a further 2 years of design work would be required. The total delay in the program, and notably the start of construction, would therefore be 4 years.

The acquisition phase timelines and real expenditure profiles are offset by 4 years as given by the calculated delay in the restart of the development phase; beyond this, the timelines and expenditure profiles mirror those of the Type 26-based CSC program. Thus, rather than beginning construction of the first CSC in 2023-24, construction begins in 2027-28, and the delivery of the 15th ship is delayed from 2044-45 to 2048-49.

Design Change Costs, Scenario 1

To the extent possible, our estimates include costs associated with the cancellation of the current project. We account for the following costs:

- Sunk costs of the Type 26 program that are otherwise unrecoverable;
- Contract termination and legal costs;
- Project costs arising from a 4-year delay; and,
- Any redundant costs that must be incurred in the event of the selection of a new design.

Excluded Design Change Costs, Scenario 1

Several important categories of costs are not included in this analysis. These are:

- The cost of extending the life of the current Halifax-class fleet of frigates, which may be necessary to bridge a 4-year gap in the delivery of new frigates;
- Any costs arising from a 4-year interruption of production at the partner shipyard, Irving Shipbuilding Inc., including any impacts this interruption may have on subcontractors; and,
- Any additional costs associated with legal proceedings and contract liabilities that are otherwise not already included.

Scenario 2 - Hybrid Build: 3 Type 26, 12 Alternate

In the second scenario, the first three ships of the CSC program retain the Type 26 design, while a new competitive process is launched in order to select the design of the remaining 12 ships. The current Type 26-based program continues exactly as currently planned until just prior to the beginning of the construction of the 4th ship, with construction activities taking place concurrently with the design selection process and the subsequent design work that would take place after the process is concluded.

In principle, under a mixed build scenario, DND may opt to procure more than three Type 26 ships. We select this amount as it is the fewest number of ships that could be procured while allowing enough time for a new competitive design selection and refinement process to be completed such that there is no significant interruption in production.

The new development phase would progress exactly as described in scenario 1, being initiated in the middle of the 2021-22 fiscal year and taking four years to reach the current state of maturity of the Type 26 program. We assume DND has adequate capacity, or could obtain adequate capacity, to manage this concurrent procurement without experiencing any additional delays in the development phase. As the Type 26 program would proceed concurrently, we assume there would be no additional delay to the start of construction of these vessels.

Compared to the currently projected timelines for the Type 26, we estimate a moderate delay in the start of production of the 4^{th} ship (the first ship of the new design) and implement a penalty to the assumed level of productivity due to the change to the new design. This results in an additional one-year delay in deliveries for ships 4-15 such that the final ship is delivered in Fiscal Year 2045-46.

While outside the scope of this report, we note that there could be costs associated with supporting two fleets of ships instead of one.

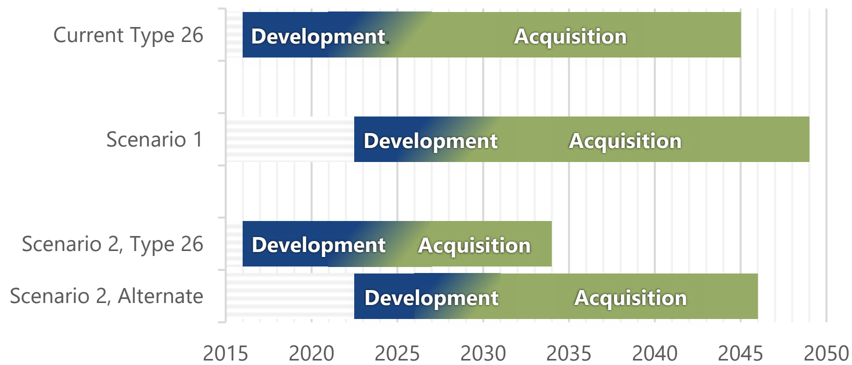
Design Change Costs, Scenario 2

In this scenario, we account for all expenditures that would be necessary to select a new design and complete all necessary design activities needed for production, as well as all expenditures currently planned to complete the design activities for the Type 26. Beyond this, we assume there would be no further costs associated with the changing of the design for the final 12 ships of the program.

Scenario Timeline Comparison

Figure 3-1 presents an estimated profile of the progression of the CSC program under scenarios 1 and 2. The current Type 26-based CSC program is slated for deliveries to begin occurring in the 2030-31 fiscal year with an assumed final delivery in the 2044-45 fiscal year. Scenario 1 reflects a similar timeline, with a shortened development phase and deliveries beginning (and completing) 4 years later. Scenario 2 displays the concurrent acquisition of 3 Type 26 vessels alongside the new development and acquisition phases to acquire 12 alternate vessels; compared to the baseline Type 26 scenario, the final vessel in this scenario would be delivered 1 year later.

Figure 3-1 Timeline of scenarios 1 and 2



Sources: PBO Calculations, Department of National Defence
Notes: Horizontal axis represents fiscal years.

3.3. FREMM

As previously indicated, we tailor our estimates to the specifications of the United States variant of the FREMM, the Constellation-class frigates, which are geared towards a general-purpose mission set similar to the Type 26.

A detailed description of our estimation process for the development and acquisition phase costs for both scenarios of the assumed FREMM procurement is available in Appendix B:B.

Briefly, we use an "analogue"[24] approach to estimate the cost of an assumed Canadian FREMM procurement project based on the known real costs[25] of Flight IIA of the United States Arleigh Burke destroyer program, while adjusting for differences in ship characteristics, shipyard productivity, jurisdictional sales tax rates, and exchange rates. Development phase and acquisition phase costs are plotted over time identically to those specified by DND for the Type 26 program, with the exception of a shorter design selection and reconciliation process for the development phase and either an assumed 4-year delay in the start of production in the first scenario or a penalty in the learning curve of the 1st FREMM ship in the second scenario.

In the final step, PBO's projected economic inflation rates and shipbuilding inflation are applied to the cost profiles.

Results

Table 3-1 displays the estimated costs for the FREMM project in scenarios 1 and 2. Both scenarios have the same development phase cost subtotal of approximately $3.7 billion. Scenario 1 acquisition phase costs total $65.5 billion and additional project costs of $1.9 billion, producing a total cost of $71.1 billion. Of this total, approximately $8 billion accounts for costs associated with the four-year delay in the start of construction.

Scenario 2 has a significantly less expensive acquisition phase, producing 12 FREMM vessels for a total of $51.0 billion. This scenario also calls for the completion of the current Type 26 development phase and the production of 3 ships of this type; these costs total $17.2 billion. This produces a total scenario cost of $71.9 billion.

Table 3-1 **Estimated FREMM project costs, scenarios 1 and 2**

All figures $ billions CAD	**Scenario 1**	**Scenario 2**
Development Phase		
Project Management	0.6	0.6
Design	3.1	3.1
Development Subtotal	**3.7**	**3.7**
Acquisition Phase		
Project Management	1.5	1.2
Construction and Other *	64	49.9
Acquisition Subtotal	**65.5**	**51**
Additional Costs		
Design Change and Sunk Costs	1.9	N/A
Type 26: development and acquisition costs for first 3 ships	N/A	17.2
Additional Cost Subtotal	**1.9**	**17.2**
Total Scenario Cost	**71.1†**	**71.9**

Sources: PBO Calculations, Department of National Defence.
Notes: Totals may not add due to rounding. All costs represented in nominal terms. Acquisition costs include an initial 2-year supply of spares.
***** "Other" costs include studies and engineering support, testing and evaluation, infrastructure, and ammunition.
† Scenario 1 total costs include the calculated cost of delaying the CSC program by 4 additional years. Of the total, approximately $8 billion is due to the delays in the development and acquisition phases.

3.4. Type 31e

The PBO cost estimates for the Type 31e are developed using an analogue approach similar to that which was used to estimate the costs of the FREMM. A detailed description of this process is available in Appendix C:.

Different from the FREMM estimates, the analogue used for the Type 31e is Denmark's Iver Huitfeldt class of frigate, which is the exact design upon which the Type 31e is based; we therefore have relatively fewer adjustments to make in order to account for differences in ship specifications.

As in the case of the FREMM, costs are plotted according to DND's own real expenditure profile of the Type 26 program, with a shortened development phase and either a four-year delay in the start of construction (scenario 1) or a learning curve penalty in the construction of the 1st ship of the Type 31e design following the 3 initial Type 26 vessels (scenario 2). Costs are then inflated using PBO's projected inflation rates and shipbuilding inflation.

Results

Table 3-2 displays the estimated costs for Type 31e project scenarios 1 and 2. Both scenarios have identical development phase costs of approximately $1.8 billion. Our estimate of Scenario 1 acquisition phase costs is $23.8 billion with additional project costs of $1.9 billion, resulting in a total cost of $27.5 billion. Of this total, approximately $3 billion accounts for costs associated with the four-year delay in the start of construction.

The second scenario, producing 3 fewer Type 31e vessels, has an acquisition phase cost of $18.5 billion, with another $17.2 billion for the completion of the Type 26's development phase and production of 3 vessels. This scenario has an estimated total cost of $37.5 billion.

Table 3-2 Estimated Type 31e project costs, scenarios 1 and 2

All figures $ billions CAD	**Scenario 1**	**Scenario 2**
Development Phase		
Project Management	0.6	0.6
Design	1.2	1.2
Development Subtotal	**1.8**	**1.8**
Acquisition Phase		
Project Management, Infrastructure and Ammunition	3.3	2.5
Construction and Other *	20.6	16
Acquisition Subtotal	**23.8**	**18.5**
Additional Costs		
Design Change and Sunk Costs	1.9	N/A
Type 26: development and acquisition costs for first 3 ships	N/A	17.2
Additional Cost Subtotal	**1.9**	**17.2**
Total Scenario Cost	**27.5†**	**37.5**

Sources: PBO Calculations, Department of National Defence.
Notes: Totals may not add due to rounding. All costs represented in nominal terms. Acquisition costs include an initial 2-year supply of spares.

***** "Other" costs include studies and engineering support as well as testing and evaluation.
† Scenario 1 total costs include the calculated cost of delaying the CSC program by 4 additional years. Of the total, approximately $3 billion is due to the delays in the development and acquisition phases.

3.5. Comparison to Other Estimates

In this section, we compare our cost estimates for the FREMM and Type 31e to reported estimates from other sources.

Type 26 Estimates

The United Kingdom's Royal Navy awarded a contract of ₤3.7 billion to BAE Systems for the manufacture of the first three Type 26 ships in 2017.[26]

The ₤3.7 billion contract would suggest a cost of ₤18.5 billion or $31.3 billion CAD for a fleet of 15 ships.[27] This is lower than DND's estimated project cost of $56-60 billion.

This comparison assumes a linear relationship between the number of ships and the cost. It is likely that BAE Systems' shipyard in Glasgow, Scotland are more experienced than Irving Shipbuilding in Canada, allowing for greater efficiency and productivity, even for the first three ships. It is also unclear exactly what is included in the ₤3.7 billion contract, making the comparison difficult.

FREMM Estimates

The Congressional Budget Office has projected a cost of approximately $12 billion real 2020 US dollars,[28] or approximately $16 billion CAD (using the average 2019-20 USDCAD exchange rate) for a production run of 10 hulls of the Constellation-class frigate. Assuming a linear relationship between ship quantity and cost, this suggests a procurement cost of 15 vessels for approximately $24 billion real 2020 CAD. This estimate is significantly lower than this report's estimate of $71 billion CAD for 15 vessels.

We did not conduct a fulsome reconciliation of the CBO numbers. However, we may explain the differences in our figures as follows.

While the CBO figures are adjusted for shipbuilding inflation, they exclude greater economy-wide inflation; this is common practice for CBO shipbuilding estimates. PBO shipbuilding estimates are always expressed in nominal terms and so include all applicable inflation factors. In addition, the construction schedule of the CSC extends well into the 2040s; based on recent US Navy budget submissions, appropriation plans for the

Constellation-class suggest the delivery of 10 of the ships by the early 2030s.[29] As such, a significant proportion of the difference may be explained by production timelines and inflation alone.

Further, there exist important productivity and shipbuilding capacity differences between the United States and Canada. Our estimates account for these differences and suggest an approximate 55% unit labour cost premium (that is, cost per like unit of work) for naval shipbuilding in Canada. We explain this process in greater detail in Appendix B:B.

Finally, the CBO figures do not include all cost categories accounted for in our analysis. In particular, governmental project management costs are not included for either the development or acquisition phases.

Type 31e Estimates

There are no independent cost estimates of the UK's Type 31e procurement program. We rely instead on the reported budget envelope of £2 billion pounds, or approximately $3.4 billion CAD (using the average 2019-20 GBP/CAD exchange rate) for the procurement of 5 Type 31e vessels; these figures are inclusive of both the development and acquisition phases, using cost categories similar to those that have been accounted for in our own analysis.

Assuming a linear relationship between procurement cost and quantity of vessels, these figures suggest a cost of approximately $10.2 billion for 15 Type 31e as compared to the PBO estimate of $27.5 billion. The difference may be explained by the following factors.

As in the case of the FREMM, we assume a much longer build timeline, both from the perspective of the start of construction and the delivery of the vessels and the length of time it would take to construct each individual vessel. The UK's first Type 31e is due to begin construction this year with delivery anticipated in 2027;[30] even if this lengthy first-ship-of-class schedule applied to all follow-on ships, it remains shorter than the assumed 7.5-year-per-ship build time assumed in the CSC project.

There also likely exists a significant disparity in labour unit costs between the UK and Canada. For our estimates, using Denmark's Iver Huitfeldt construction program, we calculated a labour unit cost premium of approximately 58%; if the UK's own estimates were based on a similar productivity as that of Denmark, this could explain a portion of the gap in our estimates. Further detail regarding our calculation of the disparity in unit labour costs between Denmark and Canada may be found in Appendix C:.

Appendix A: Comparison to 2019

Our new estimate of the cost of the CSC procurement project represents an 11% increase as compared to 2019 report. This section provides greater detail on the factors that led to this increase in the estimated project cost.

The projected lightship weight of the Type 26-based CSC has increased from 6,900 to 7,800 metric tonnes, which results in a corresponding increase in cost based on the model's cost estimating relationships. However, these relationships have since been updated to incorporate greater granularity, allowing for separate cost estimating relationships based on the Ship Work Breakdown Structure (SWBS) category; as a significant portion of the weight increase was allotted to SWBS elements with less pronounced cost estimating relationships, this has somewhat mitigated the increase in cost.[31]

We reduced the assumed learning curve percentage to reflect new information provided by DND; this results in a minor increase in cost. In our previous reports, the learning curve percentage was calibrated to the estimated learning curve from the Canadian Patrol Frigate program which was steeper than our current assumption. Further, we reduce the scope of the learning curve to a narrower definition of labour costs, increasing our cost estimate.[32]

The revised project schedule, which indicates delays in the start of construction, resulted in a slight decrease to our cost estimate rather than an increase.[33] This is because our latest estimate incorporates DND's projected expenditure profile which, compared to our previous assumptions, suggests more money is spent in the earlier part of each ship's construction. Our 2019 report had assumed a linear distribution over the production schedule of each ship. The overall effect of our latest approach is that compared to our 2019 estimate, a slightly larger proportion is allocated up-front relative to outer years which are subject to increasing inflation adjustments.

We estimate the development and ancillary acquisition costs by applying the proportion of these costs relative to construction as estimated by DND, and apply it to our independent cost estimate of production. After aligning the inflation to DND's revised schedule, this change resulted in a minor increase in the projected costs for these categories.[34]

Our updated CPI decreased our costs. No changes were made to our assumptions surrounding shipbuilding inflation.[35]

Two years' worth of spare parts (spares) were re-estimated by inflating our 2019 estimate to 2019-20 dollars, adding a 10 per cent provincial sales tax, scaling up with the new LSW according to our updated CER, and inflating according to DND's schedule and PBO's CPI and shipbuilding inflation.[36]

Finally, consistent with our update to the JSS report, we exclude federal sales tax as a cost which was included in the 2019 estimate, since it also represents a source of revenue to the federal government. This resulted in a slight decrease to our cost estimate relative to 2019.

The resulting increases outweighed the downward revisions, resulting in an overall increase to our cost estimate relative to our 2019 report.

Appendix B: FREMM Model

As the Constellation-class frigates are not yet in active service, we adopt an "analogue" approach for the purposes of developing an independent cost estimate of the construction costs for the two scenarios. This approach consists of identifying a historical procurement program for a ship class that is similar to the ships being produced in the future and for which costs are fully known.[37]

Development phase costs are also calculated for each scenario. These are estimated based on data provided by DND, adjusted to reflect construction cost differences between the FREMM and the Type 26. We assume the cost of conducting a new competition and design selection process would be the same in real terms as the previous process that selected the Type 26 design, however with a shorter timeframe of approximately two years. The costs associated with purchasing the design and completing all subsequent design work are assumed to be proportional to the independently estimated construction cost of the FREMM using the relationships in DND's cost detail for the Type 26. The costs are then plotted over time using a cost distribution mirroring that of the Type 26.

To calculate construction costs, we base our analogue approach on the United States Navy's Arleigh Burke-class destroyer using procurement data provided by the Congressional Budget Office. This base cost data accounts for all construction activities as well as the following ancillary acquisition phase costs: studies, analysis and engineering support; system test, trials and evaluation; infrastructure; and ammunition. As such, our analogue approach will account for each of these cost categories as well; any remaining ancillary cost categories – notably, departmental project management costs for the acquisition phase – are calculated in the same manner as design costs, that is, using the proportion of the given element in the breakdown of Type 26 costs to construction costs.

Typically, an analogue approach would begin by estimating the cost of the first ship in a production line, using learning curves and other adjustments to calculate the cost of follow-on vessels. As the Arleigh Burke class has been in near-continuous production since the early 1980s, with several iterations or "Flights" representing incremental steps in the evolution of the warship, we opt to isolate a production run of a single Flight (IIA), using an average cost of a set of ships within this production run as a basis upon which to calculate a 9th ship cost of a potential Canadian variant of the FREMM. This average cost is then escalated using United States CPI and shipbuilding inflation to the 2020 fiscal year. The 2020 real costs of ships 1 through 8 and 10 through 15 are then extrapolated from the estimated 9th ship cost using a learning curve.[38] The total proportion of labour costs to material costs of construction is assumed to be 30%.

The Arleigh Burke class of destroyers are larger and generally have a broader set of capabilities than most frigate classes in active service. To reflect how these factors would affect the estimated construction cost, we adjust for differences in lightship weight; the Flight IIA Arleigh Burke destroyer has a lightship weight of approximately 7,205 tonnes, while the lightship weight of the Constellation-class frigate is projected to be 6,110 tonnes. The calculated real base cost of each ship is thus reduced by approximately 15%.

We also account for anticipated differences in labour productivity between the shipyards responsible for the construction of the Arleigh Burke destroyers (Bath Ironworks in Bath, ME, and Huntington Ingalls in Pascagoula, MS) and Irving's shipyard in Halifax, NS. Using aggregated industry data, we calculate a unit labour cost to productivity differential of approximately 1.55, resulting in a 55% increase in the estimated real cost of labour.

To account for tax differentials, we use the difference in the provincial and state statutory tax rates for the Irving Shipyard in 2020 (10%) and a weighted average of the tax rates for the Bath Ironworks and Huntington Ingalls shipyards (6.17%).[39] We therefore adjust the real cost estimate upwards by a factor of approximately 1.02.

Converting real costs to $CAD using the average 2019-20 Fiscal Year USDCAD exchange rate ($1.3306), we then plot construction costs over time using a distribution that mirrors that of DND's anticipated Type 26 expenditure profile, with a delay in the start of construction of 4 years, and inflate with PBO's CPI projection as well as shipbuilding inflation.

Appendix C: Type 31e Model

As in the case of the Constellation-class frigate, there are as yet no Type 31e vessels in service, and so historical construction costs are not yet available. Instead, we rely on the costs of Denmark's Iver Huitfeldt-class of frigate, which is the design upon which the Type 31e is based.[40] It is of recent vintage, with 3 hulls jointly produced by the Danish government and prime industry contractor Odense Maritime Inc. between 2008 and 2014. Due to very similar design characteristics, relatively few adjustments need to be made to account for differences in capabilities.

Development and acquisition costs were calculated in the same manner as in the FREMM model (Appendix B:) with the following exceptions:

- The base cost data is inflated to the 2020 fiscal year using Denmark's domestic CPI and an assumed shipbuilding inflation rate of 1.2% from 2010 to 2015 and 0.9% from 2016 to 2020.
- The cost data does not include the cost of (a) infrastructure or (b) ammunition: these are instead calculated using the proportion of these elements in the DND breakdown of Type 26 costs to construction costs and applied to the independent estimate of Type 31e costs;
- Costs for follow-on ships 2 through 15 are calculated based on the inferred cost of the 1st ship of the Iver Huitfeldt class;
- The Iver Huitfeldt's calculated labour percentage is 23.6%[41];
- There is only a minor increase in cost (1.8%) to account for capability differences between the Type 31e and the Iver Huitfeldt as proxied by the lightship weight differential;
- The productivity differential between Denmark's Odense Maritime shipyard and Irving Shipbuilding Inc. is calculated using a labour-cost-per-ton-of-steelwork metric that indicates a unit labour cost to productivity differential of approximately 1.58, resulting in a 58% increase in the estimated cost of labour;
- Taxes of any kind are excluded in the Iver Huitfeldt base data; we thus apply a full 10% increase in costs to account for provincial sales taxes in the domestic Type 31e build; and,
- The currency conversion step converts from Danish kroner to Canadian dollars, using the average DKK/CAD exchange rate for the 2020 fiscal year (approximately 0.198 CAD per DKK).

Costs for the development and acquisition phases are plotted exactly as described in the FREMM model section, incorporating a shortened development phase and a four-year delay in the start of construction, and otherwise matching DND's planned real expenditure profile over time. Costs are inflated according to the PBO projection of Canadian CPI and shipbuilding inflation.

Notes

[1] Canada, Parliament, House of Commons Standing Committee on Operations and Estimates, *Minutes of Proceedings and Evidence,* 43rd Parl, 1st Sess, No 21 (19 June 2020) URL: https://www.ourcommons.ca/DocumentViewer/en/43-1/OGGO/meeting-21/minutes

[2] Department of National Defence (accessed 4 February 2021). Canadian Surface Combatants, from http://www.navy-marine.forces.gc.ca/en/fleet-units/csc-home.page

[3] Department of National Defence, (accessed 4 February 2021). Canadian surface combatant, from https://www.canada.ca/en/department-national-defence/services/procurement/canadian-surface-combatant.html

[4] Congressional Research Service. December 2020. "Navy Constellation (FFG-62) Class Frigate (Previously FFG[X]) Program: Background and Issues for Congress". https://crsreports.congress.gov/product/pdf/R/R44972/71 (accessed 15 January 2021)

[5] United Kingdom House of Commons Defence Committee, "Restoring the Fleet: Naval Procurement and the National Shipbuilding Strategy", Third Report of Session 2016-17. https://publications.parliament.uk/pa/cm201617/cmselect/cmdfence/221/221.pdf (accessed 21 January 2021)

[6] United Kingdom House of Commons Defence Committee, "Restoring the Fleet: Naval Procurement and the National Shipbuilding Strategy", Third Report of Session 2016-17. https://publications.parliament.uk/pa/cm201617/cmselect/cmdfence/221/221.pdf (accessed 21 January 2021)

[7] Canada, Parliament, House of Commons Standing Committee on Operations and Estimates, *Minutes of Proceedings and Evidence,* 43rd Parl, 1st Sess, No 21 (19 June 2020) URL: https://www.ourcommons.ca/DocumentViewer/en/43-1/OGGO/meeting-21/minutes

[8] For a detailed methodology, see our previous report: Parliamentary Budget Officer. (June 2019). The Cost of Canada's Surface Combatants: 2019 Update. URL: https://www.pbo-dpb.gc.ca/en/blog/news/canada-surface-combatants-2019-update

[9] Parliamentary Budget Officer. (November 2020). The Joint Support Ship program and the MV Asterix: a Fiscal Analysis. URL: https://www.pbo-dpb.gc.ca/en/blog/news/RP-2021-029-C--joint-support-ship-program-mv-asterix-fiscal-analysis--programme-navires-soutien-interarmees-nm-asterix-analyse-financiere

[10] See Lee Berthiaume, "National Defence grappling with new delay in $60B warship project", *The Canadian Press*, February 2, 2021. URL: https://www.nationalnewswatch.com/2021/02/02/national-defence-grappling-with-new-delay-in-60b-warship-project-3/#.YBmD6uhKiUm and Department of National Defence. (accessed 3 February 2021). Canadian

surface combatant, URL https://www.canada.ca/en/department-national-defence/services/procurement/canadian-surface-combatant.html

[11] Based on information provided by the Department of National Defence in response to PBO Information Request IR #0502, 2021; URL to response: https://www.pbo-dpb.gc.ca/web/default/files/Documents/Info%20Requests/2020/IR0502_response_b.pdf

[12] 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/projetsprojects-eng.html

[13] Parliamentary Budget Officer. (2017). The Cost of Canada's Surface Combatants. URL: https://www.pbo-dpb.gc.ca/en/blog/news/CSC_costing

[14] Department of National Defence. (accessed 4 December 2020). Canadian surface combatant, from https://www.canada.ca/en/department-national-defence/services/procurement/canadian-surface-combatant.html

[15] See section 2 and Appendix B in: Parliamentary Budget Officer. (June 2019). The Cost of Canada's Surface Combatants: 2019 Update. url: https://www.pbo-dpb.gc.ca/en/blog/news/canada-surface-combatants-2019-update

[16] The FREMM acronym stands for "Frégate européenne multi-mission" in French and "Fregata europea multi-missione" in Italian.

[17] Congressional Budget Office. October 2020. "The Cost of the Navy's New Frigate". https://www.cbo.gov/publication/56669 (accessed 15 January 2021)

[18] Congressional Research Service. December 2020. "Navy Constellation (FFG-62) Class Frigate (Previously FFG[X]) Program: Background and Issues for Congress". https://crsreports.congress.gov/product/pdf/R/R44972/71 (accessed 15 January 2021)

[19] United Kingdom House of Commons Defence Committee, "Restoring the Fleet: Naval Procurement and the National Shipbuilding Strategy", Third Report of Session 2016-17. https://publications.parliament.uk/pa/cm201617/cmselect/cmdfence/221/221.pdf (accessed 21 January 2021)

[20] Naval News. November 2019. "UK MoD Formally Awards Type 31 Frigate Contract To Babcock". https://www.navalnews.com/naval-news/2019/11/uk-mod-formally-awards-type-31-frigate-contract-to-babcock/ (accessed 21 January 2021)

[21] United Kingdom House of Commons Defence Committee, "Restoring the Fleet: Naval Procurement and the National Shipbuilding Strategy", Third Report of Session 2016-17. https://publications.parliament.uk/pa/cm201617/cmselect/cmdfence/221/221.pdf (accessed 21 January 2021)

[22] UK Defence Journal. May 2018. "Babcock launches 'Team 31', selects Arrowhead 140 design for Type 31e frigate competition". https://ukdefencejournal.org.uk/babcock-launches-team-31-selects-arrowhead-140-design-for-type-31e-frigate-competition/ (accessed 20 January 2021)

[23] For example, if the first ship of the Type 26 production run is slated to incur 5% of its total real expenditure in 2024-25, we assume that a four-year delay for an alternate design would mean that 5% of the real expenditure for its first ship would occur in 2028-29.

[24] For further information, see, for instance: Congressional Budget Office, "How CBO Estimates the Cost of New Ships", April 2018. URL: https://www.cbo.gov/system/files/115th-congress-2017-2018/reports/53785-cost-estimates-new-ships.pdf

[25] Costs are first inflated using United States domestic CPI and shipbuilding inflation to the 2020 fiscal year.

[26] See BAE Systems, Manufacturing contract for Type 26 Global Combat Ship awarded to BAE Systems (accessed 4 February 2021) https://www.baesystems.com/en-uk/article/manufacturing-contract-for-type-26-global-combat-ship-awarded-to-bae-systems

[27] Assuming an exchange rate of 1.690. PBO set the time frame from April 1, 2019 to March 31, 2020 at Investing.com url: https://ca.investing.com/currencies/gbp-cad-historical-data

[28] Congressional Budget Office. October 2020. "The Cost of the Navy's New Frigate". https://www.cbo.gov/publication/56669 (accessed 15 January 2021)

[29] Inferred based on construction schedule of first ship (delivery by 2026) and US Navy budget appropriations. Department of Defense, United States. "Fiscal Year (FY) 2020 President's Budget Estimate Submission; Shipbuilding and Conversion, Navy".

[30] Navy Lookout. February 2020. "Only seven years to wait until the Royal Navy gets a new frigate". https://www.navylookout.com/only-seven-years-to-wait-until-the-royal-navy-gets-a-new-frigate/ (accessed 22 January 2021)

[31] A study by RAND suggests that a 1% increase in LSW would increase costs by 0.96%. See: Arena, Mark V., Irv Blickstein, Obaid Younossi, and Clifford A. Grammich. "Why Have Navy Ship Costs Risen?." (2006). URL: https://www.rand.org/pubs/research_briefs/RB9182.html

[32] PBO used information from DND to estimate the proportion of labour costs (40%).

[33] The schedule information provided by DND is consistent with what was reported in the news recently. See Lee Berthiaume, "National Defence grappling with new delay in $60B warship project", *The Canadian Press*, February 2, 2021. URL: https://www.nationalnewswatch.com/2021/02/02/national-defence-grappling-with-new-delay-in-60b-warship-project-3/#.YBmD6uhKiUm

[34] We deflated these adjusted development costs by CPI plus shipbuilding inflation, and re-inflated using only CPI over the development schedule. That is, we do not expect development to experience shipbuilding-specific inflation.

[35] Source for PBO's CPI is our Economic and Fiscal Outlook, September 2020, URL: https://www.pbo-dpb.gc.ca/en/blog/news/RP-2021-027-S--economic-fiscal-outlook-september-2020--perspectives-economiques-financieres-septembre-2020. Shipbuilding inflation is unchanged from our Joint Support Ship Report. See: Parliamentary Budget Officer. (November 2020). The Joint Support Ship program and the MV Asterix: a Fiscal Analysis. URL:

https://www.pbo-dpb.gc.ca/en/blog/news/RP-2021-029-C--joint-support-ship-program-mv-asterix-fiscal-analysis--programme-navires-soutien-interarmees-nm-asterix-analyse-financiere

[36] PBO assumed that spares would follow the same schedule as acquisition project management and infrastructure and facilities. That is, the cost of spares were inflated using PBO's CPI and shipbuilding inflation by assuming their allocation over time reflects that of project management for acquisition and infrastructure and facilities.

[37] For further information on the analogue approach to costing naval ships, see: Congressional Budget Office, "How CBO Estimates the Cost of New Ships", April 2018. URL: https://www.cbo.gov/system/files/115th-congress-2017-2018/reports/53785-cost-estimates-new-ships.pdf

[38] The 9th ship cost is selected as in naval shipbuilding, the 9th ship is considered the point at which further efficiencies from learning are all but eliminated.

[39] PBO could not obtain the shipyard-specific effective tax rates to accurately account for the tax differential in building the T-AKE-1 and the JSS. For San Diego, the tax rate reflects local (state) and city sales taxes. See: California Department of Tax and Fee Administration, Forms and Publications, Form CDTFA-105: District Taxes, Rates, and Effective Dates. URL: https://www.cdtfa.ca.gov/formspubs/cdtfa105.pdf for San Diego; Urban Institute & Brookings Institution, Tax Policy Center Statistics, State Sales Tax Rates. URL: https://www.taxpolicycenter.org/statistics/state-sales-tax-rates For Vancouver, the tax rate reflects the provincial sales tax. See: British Columbia, Provincial Sales Tax. URL: https://www2.gov.bc.ca/gov/content/taxes/sales-taxes/pst, Accessed September 18, 2020.

[40] Data on the Iver Huitfeldt was provided by Odense Maritime Technology, with supplementary information on the Type 31e provided by Babcock International.

[41] This relatively low percentage of labour reflects a moderate share of much of the construction and a low share associated with installation of combat systems and labour used to install reused material. The Iver Huitfeldt platform is designed for the quick installation and replacement of weapon systems and other equipment, which may explain the lower labour portion of installation costs.