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THE JOINT SUPPORT SHIP PROGRAM AND THE MV ASTERIX: A FISCAL 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 from the House of Commons Government Operations and Estimates Committee (OGGO), this report estimates the construction costs of the Joint Support Ship program to build two supply ships and costs of contracting converted commercial vessels named the MV Asterix and the Obelix to provide military support. This report also attempts to compare the two projects by incorporating additional project cost elements.

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 also grateful to the Congressional Budget Office for their assistance in obtaining cost data on the Lewis and Clark-class replenishment vessels.

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Executive Summary

On June 9, 2020, the House of Commons Government Operations and Estimates Committee (OGGO) requested that the Office of the Parliamentary Budget Officer prepare an independent cost estimate for the construction of the two Joint Support Ship (JSS) vessels in Canada, as well as for contracting similar capacity from Chantier Davie Canada Inc. (Davie).[1]

The JSS project aims to deliver two new support ships to the Royal Canadian Navy, replacing legacy Protecteur-class auxiliary oiler replenishment vessels decommissioned in the last decade. With the two new vessels to be delivered in 2023 and 2025, the Government of Canada contracted Davie to convert a commercial vessel, the MV Asterix, to military support ship specifications to maintain the Navy's at-sea replenishment capability. The Asterix was converted and delivered on-time and on-budget and has been operationally active since 2018; it is currently under contract for a five-year span ending in the 2022-2023 fiscal year. Davie has since offered the government an option to contract a second vessel, the Obelix.

Joint Support Ship Costs

Our independent point estimate of the construction cost is $2.4 billion, with an additional estimated $0.6 billion to account for budgetary contingency, producing a total of $3.0 billion. The Department of National Defence estimates the construction cost at approximately $3.1 billion, including budgetary contingencies and contractor incentives; $3.3 billion after accounting for a 7 per cent provincial sales tax. These estimates are comparable to those of our independent analysis.

Accounting for the non-construction costs stated by the Department of National Defence, we estimate the total project cost of the JSS of $4.1 billion, inclusive of provincial sales tax.[2] This is comparable to the $4.1 billion published by the Department of National Defence, though slightly lower after adjusting that number to include provincial sales tax ($4.4 billion).

MV Asterix Contract and Purchase Costs

The total potential net cost of the government's contracting of the MV Asterix is $733 million, inclusive of provincial sales tax. Of this total, approximately $453 million concerns fixed payments to the contractor while the remainder is variable and subject to operational and project requirements. The contract may be extended at a total cost to the

government of roughly $100 million per year, increasing with inflation, up to a maximum of five years.

The Department of National Defence had the option to purchase the vessel upon delivery in 2018 at a base price of $658 million, or $724 million with applicable taxes. The government may still opt to purchase the vessel at any time. We estimate that the vessel could be purchased at the expiry of the 5-year contract for $633 million, taxes included. Similar to our estimate of the JSS program, these purchase costs include only the acquisition of the ship and do not include any operations and maintenance or ancillary project management and administrative costs.

Obelix Contract and Purchase Costs

Basing the projected contract costs of the Obelix on the known costs of the MV Asterix, we project that a five-year provision of service contract beginning at the start of the 2023-24 fiscal year would cost the government $801 million, inclusive of any applicable taxes. Of this total, $489 million would account for fixed costs, $215 million would account for variable costs, and $97 million would cover ancillary non-contract costs. We estimate that a purchase of the Obelix in 2023-2024 would cost $797 million, exclusive of any operations and maintenance or ancillary project costs but including taxes.

Comparing JSS Project Costs and Asterix and Obelix Costs

The cost of the provision of service contracts of the Asterix or the potential Obelix cannot be directly compared to the project costs of the JSS. To enable a more apt comparison of the costs of these ships, we construct a scenario in which the Asterix and Obelix are both purchased at the end of the 2022-23 fiscal year, when the initial five-year contract of the Asterix expires. Net of any costs associated with this initial contract, we estimate a total cost of approximately $1.4 billion for the purchase of two Davie vessels. This is lower than the government's JSS project cost of $4.4 billion ($4.1 billion plus a 7 per cent provincial sales tax), and our estimate of the JSS project of $4.1 billion.[3]

An assessment of the capabilities of the Asterix and Obelix as commercial vessels converted for military purposes versus those of the built-for-purpose Joint Support Ship is outside the scope of this report.

1. Introduction

The Joint Support Ship (JSS) program was launched by the government of Canada in 2004 in order to replace the Royal Canadian Navy's aging fleet of legacy Protecteur-class Auxiliary Oiler Replenishment (AOR) vessels.[4] AOR vessels provide logistical support to combat vessels. This typically includes underway support for refueling, ammunition, spare parts and other supplies while at sea. They can also offer some additional support capabilities, such as the ability for military helicopters to land upon the vessel and carry out support activities to on-shore operations.

Originally planned to deliver three ships, with the first to be operational by 2012, the JSS program has since suffered from numerous delays, increases in cost, and changes in project scope.[5]

The program now calls for the procurement of two vessels. Construction of the first vessel, the HMCS Protecteur, officially began in June 2018, with delivery to the Royal Canadian Navy (RCN) scheduled in 2023 and attaining operational capability in 2024.[6] The second ship, HMCS Preserver, is to be delivered and achieve operational status in 2025 with operational capability being achieved the following year. The Department of National Defence (DND) has, however, stated that the delivery schedule of the second ship is currently under review.[7]

The delays in the JSS program coupled with the earlier than anticipated decommissioning of the legacy Protecteur-class vessels required the Canadian Armed Forces (CAF) to adopt interim solutions. First, this included contracting the use of foreign replenishment vessels to temporarily fill the AOR role for the Royal Canadian Navy (RCN). More recently, the CAF launched Project Resolve, the contracting of Chantier Davie Canada Inc. (Davie) to convert a container ship, the MV Asterix, to auxiliary replenishment ship specifications. The ship was converted and delivered on-time and on-budget and has been operationally active since 2018. Davie has since offered the government an option to contract a second vessel, the Obelix.

On June 9, 2020 the House of Commons Government Operations and Estimates Committee (OGGO) requested that the Office of the Parliamentary Budget Officer (PBO) provide an independent cost estimate for construction costs of the Joint Supply Ship in Canada, and for the leasing of the Davie's Asterix.[8]

In the spirit of this request, this report presents cost estimates of the JSS program and the costs associated with the provision of service contracts and purchase options of the Asterix and Obelix. Specifically, this report includes:

- An independent estimate for the construction cost of the JSS program to deliver two vessels;
- The analysis of the costs of the MV Asterix's Provision of Service contract and an independent estimate of its purchase cost, and purchase option costs for the MV Asterix;
- An independent estimate for the potential of contracting and purchase of a second supply ship, the MV Obelix; and,
- JSS program costs other than construction, as published by the Department of Defence.

Construction costs are those directly attributable to the building and outfitting of the ship, including labour and material costs, and exclude design, development, or project management costs. For the purposes of this report, costs are calculated in nominal dollars and presented on a fiscal year basis.

In keeping with our mandate, this report presents costs only and does not include a cost-benefit analysis. The summarized system characteristics for each vessel found in this report are for information purposes only. That is, comparing and analyzing the capabilities across ships relative to their respective costs are outside the scope of this report.

The following sections explore the costs described above. The first section concerns the estimation of the construction costs of the two Joint Support Ships, presenting the scope of the analysis, the methodology and assumptions, and the final cost estimate. We include a secondary approach to estimating these costs in order to confirm the results of our primary model. The second section of this report details the costs associated with the contracting and purchase of the MV Asterix from Chantier Davie Canada Inc. The third section estimates the costs of either contracting or purchasing a second supply ship, the Obelix, from Davie. The last section presents a comparison of the costs of the JSS project and a scenario under which the government purchases the MV Asterix and Obelix.

2. Joint Support Ship

JSS Characteristics

Protecteur-class Joint Support Ship

In Service: 2024 (first ship, expected)

Length: 174m

Beam: 24m

Lightship Displacement: 11,133 tonnes

Max Speed: 20 knots

Range: 10,800 nautical miles

Replenishment-At-Sea capability: 2 multi-purpose replenishment stations, one 24-tonne crane, two 6 tonne cranes

Cargo: 8,208 tonnes of ship-type fuel (F76), 1,232 tonnes of aviation-type fuel (F44), 460 tonnes potable water, 62 containers

Aviation: 1 spot, 2 enclosed hangars capable of storing CH-148 Cyclone helicopters, can accommodate Chinook

Medical / Dental Capabilities: 4 surgical tables, 1 dental chair, NATO Role 2 – Level 3 standard

Construction costs for the JSS project are those directly attributable to the building and outfitting of the ship, including labour and material costs. Our estimate also includes the cost of spare parts and applicable taxes. As the JSS program has entered the Acquisition phase, most costs associated with design, development and project management are known and are presented separately from our independent estimate of construction costs.

To estimate the construction costs of the JSS, we employ two separate methods: an analogue approach and a parametric modelling approach.

The analogue modelling concept is the United States Congressional Budget Office's principal method of estimating ship costs.[9] It 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. We used cost data from the United States Navy's Lewis and Clark-class (designation T-AKE) replenishment vessels as our analogue. The T-AKE class has a very similar mission profile as that of the Joint Support Ship, with underway replenishment of fuel, cargo, ammunition and other supplies among its capabilities.

The parametric modelling approach relies on a model developed by Arena et. al. (2006) that estimates construction costs based on system characteristics. We use this approach to produce a second estimate to confirm the results of the analogue model.[10]

2.1. Data and Methodology

This analysis relies primarily on two data sources. The Department of National Defence provided detailed costs and system specifications for the JSS program. Construction costs for the Lewis and Clarke T-AKE class were provided by the United States Congressional Budget Office, while system characteristics were obtained from a variety of publicly available sources.[11] The specifications, costs and cash flow for the JSS were provided by DND.[12]

There are several important differences between the T-AKE and the JSS system specifications. Notably, the T-AKE is a significantly larger ship, with a lightship weight of over 25,000 tonnes compared to the JSS's approximately 11,000 tonnes and has a slightly lower density of power generation.[13] Differences in factors such as these are explicitly accounted for in the modelling process to produce a cost estimate reflective of a ship with the JSS's characteristics. In addition to differences in ship specifications, we

adjust for a variety of other factors such as the exchange rate and differences in labour costs and shipyard productivity. To account for uncertainty in our modelling assumptions, we develop a distribution of cost estimates based on historical variation in key modelling inputs. Further detail on the calculation of the main estimate and the risk and uncertainty analysis is available in Appendices A and B.

2.2. Results

Our point estimate of the total construction cost of the JSS is $2.4 billion dollars, dispersed over the 2018-19 and 2025-26 fiscal years. Accounting for risk and uncertainty in our variables, we derive an 80th percentile cost of $3.0 billion dollars; this suggests the inclusion of $0.6 billion in the budget for the purposes of contingency.

Box 2-1

Calculating Contingency

The PBO estimate of $0.6 billion for the purposes of budgetary contingency in the construction of the JSS is calculated as the difference between the 80th and 50th percentiles of the estimated cost distribution. To produce this distribution, we use Monte Carlo methods to allow for variation in several key inputs in the modelling process. Appendix B provides further information on this process.

The bulk of the construction costs peak in 2020-21 when the construction of the first ship is well underway, followed by another uptick in 2022-23 when the first ship's construction is completed, and the construction of the second ship begins in earnest.

These estimates do not assume any COVID implications on the costs or schedule of the JSS.

We also employ a second model based on regression analysis as a means of validation. The results are comparable to the $2.4 billion point estimate obtained in our analogue model. This approach is explained in Box 2-2.

Box 2-2

Estimating the JSS construction costs using regression analysis

Based on the results from a regression analysis undertaken by Arena et. al (2006), this approach estimates the cost of the JSS based on its lightship weight (LSW), class, and power density.

The equation is as follows:

$$\ln(C_9) = \beta_0 + \beta_1 \ln(LSW) + \beta_2 \ln(PowerDensity) + \beta_3 Auxiliary$$

where Auxiliary is a binary variable, used to identify whether the vessel is an auxiliary vessel, and the subscript '9' refers to the 9th ship built. The cost estimating relationships in the equation were computed for the 2005 U.S fiscal year (October to September).

Since the model is designed to estimate the cost of the 9th ship – where the cost of the vessels is expected to be at its lowest due to learning efficiencies – we inflate the cost assuming a "learning curve" of 91 per cent, consistent with the assumptions of the JSS program. The "learning curve" reflects productivity improvements at a given shipyard as workers gain experience building a certain ship specification.

The resulting estimated costs for the first and second ships are then inflated using economic and shipbuilding-specific inflation to the 2020 Canadian fiscal year. We then adjust for differences in labour costs, productivity and tax rates, and convert the resulting estimate into Canadian dollars. As a final step, we distribute the estimated construction costs over the schedule implied in the JSS project. These adjustments mirror those employed in our first approach and are described in further detail in Appendix A.

Using this alternate approach, we estimate the construction costs of the JSS will be $2.6 billion, very similar to the point estimate generated by the analogue model.

Source: Arena et. Al (2006)[14] and PBO

We also conduct a sensitivity on the impact of a single year delay for one or both ships. Assuming that delay is at the onset of the construction period, our results indicate a single-year delay in the construction of the second ship would increase costs by $34 million.[15] A one-year delay at the onset of the construction period for the first and the second ship would increase costs by $71 million.

The Department of National Defence announced that costs for all supporting design and production engineering work, project management, associated contingency costs, and historical costs associated with the project leading up to the start of design including options analysis amount to $1 billion.[16]

Accounting for provincial goods and services tax of 7 per cent brings this cost up to just under $1.1 billion.

Therefore, we estimate the total JSS program costs to be $4.1 billion, after including estimated contingencies associated with the construction phase and incorporating the remaining program costs published by the Department of National Defence with our main construction cost estimate of $2.4 billion (Table 2-1).

Table 2-1 JSS Project Costs

billions $	**Construction***	**Contingency****	**Non-Construction Project Costs†**	**Total***
Point estimate	2.4	0.6	1.1	**4.1**

Source: PBO and DND[17]

Notes: * PBO estimate inclusive of a 7 per cent provincial tax.
** PBO estimate using a Monte Carlo simulation on input variables. Further detail is described in Appendix B.
† DND-reported supporting costs of $1.0 billion plus an assumed provincial sales tax of 7 per cent.

This is comparable to the $4.1 billion announced by the Department of National Defence which does not account for applicable taxes. Accounting for a 7 per cent provincial sales tax, the Department of National Defence's estimate rises to approximately $4.4 billion, which is somewhat higher than our independent estimate of $4.1 billion.

3. The MV Asterix

MV Asterix Characteristics

MV Asterix – Resolve-Class Combat Support Ship

In Service: 2018

Length: 182.5m

Beam: 25.2m

Lightship Displacement: 15,771 tonnes

Max Speed: 21-22 knots

Range: 13,140 nautical miles

Replenishment-At-Sea capability: 4 masts (2 multi-purpose, 2 liquid-only), 2 swivel cranes

Cargo: 8,208 tonnes of ship-type fuel (F76), 1,232 tonnes of aviation-type fuel (F44), 490 tonnes potable water, 38 containers

Aviation: 1 spot, 2 enclosed hangars capable of storing CH-148 Cyclone helicopters (with modification)

Medical / Dental Capabilities: 1 surgical table, 1 dental chair, 6 medical beds, capacity to convert other spaces, NATO Role 2 – Level 3 standard

This section examines the costs of the Government of Canada's contracting of the MV Asterix combat supply ship under the purview of Project Resolve. As the costs of contracting the MV Asterix are mostly known, an independent estimate is not required. Instead, we present a breakdown of the fixed costs associated with the contract and forecast costs associated with the operations and maintenance of the vessel. Ancillary costs associated with the government's management of the project are also presented, however these costs are not included in the Provision of Service contract.

At present, the MV Asterix is under contract for a five-year period ending in 2022-23, at which point the government has up to five additional one-year options to prolong the contract. We separately examine the cost of extending the agreement for each of these additional years.

The contract governing the activities of the MV Asterix is a Provision of Service contract wherein the industry partner, Federal Fleet Services, provides the Canadian government a set of services as described within the contract's statement of work. These services include an assortment of at-sea replenishment capabilities for fuel, provisions, and munitions, as well as the provision of medical facilities and aviation operations and maintenance facilities.

Importantly, the contract does not impart ownership of the MV Asterix to the Government of Canada; the operation of the vessel is the responsibility of Federal Fleet Services. As such, the MV Asterix is a commercial vessel that is not technically part of the RCN fleet.

3.1. MV Asterix Cost Breakdown

Table 3-1 delineates the costs associated with the MV Asterix.[18] These are separated according to the fixed costs paid to the contractor and the variable costs associated with operations and maintenance activities. These costs concern only the initial five-year period from 2017-18 to 2022-23.

Table 3-1 Cost of MV Asterix Contracting

$ millions	**Cost**
Fixed Service Fee	395
Pre-Service delivery cost	40
Additional Work Requirements	18
Fixed Cost Subtotal	**453**

Service Delivery Payments (Operations)	141
Potential Additional Operations and Maintenance Costs	51
Variable Cost Subtotal	**192**
Ancillary Operations and Program Costs, outside of contract	88
Non-Contract Cost Subtotal	**88**
Total Potential Cost	**733**

Source: PBO Calculations, Department of National Defence.

Notes: Totals may not add due to rounding. Departmental cost contingencies included. Includes provincial taxes using an assumed rate of 9.975 per cent.

As of August 2020, the total potential project cost, including all fixed costs, variable costs, and ancillary non-contract costs is $733 million. All figures are inclusive of an assumed provincial sales tax rate of 9.975 per cent.[19]

The Fixed Service Fee of $395 million consists of an annually recurring cost of approximately $79 million, whereas the Pre-Service delivery cost and Additional Work Requirements are each one-time payments from the start of the contract.

While the total fixed cost of $453 million is unlikely to change, there is a potential increase in the contract value on the Service Delivery Payments item concerning variable amounts paid for operations and maintenance. These could total up to $51 million by the end of the initial five-year contract period. These amounts are already budgeted in departmental contingencies.

The Department of National Defence has forecasted up to $80 million to cover ancillary program costs, with the cost increasing to $88 million when provincial taxes are included. Ancillary program costs are outside the purview of the contract of the MV Asterix and would be incurred irrespective of the contracting arrangement. That is, these costs can be interpreted as overhead costs for managing a supply ship capability.

3.2. Projected Outyear Costs

Once the initial five-year contracting of the Asterix is completed, the Government of Canada has the option to continue the Provision of Service contract with Federal Fleet Services at a fixed rate of $36 million per annum, or approximately $40 million once applicable provincial taxes are added.

In order to continue operating the vessel, additional operations and maintenance costs and ancillary program costs would be incurred. Taking an average of the budgeted costs over the 5-year life of the contract, we project an annual operations and maintenance cost of $41 million per year and an annual expenditure on ancillary program costs of $19 million per year. These costs increase with inflation over each of the four remaining option years.

Table 3-2 presents a breakdown of these costs by year. Note that the projections of these variable costs are contingent on the assumption that the operational requirements imposed on the MV Asterix and its crew are similar to those that have occurred over the observed period.

Table 3-2 Projected Outyear MV Asterix Project Costs

$ millions	**2023-2024**	**2024-2025**	**2025-2026**	**2026-2027**	**2027-2028**
Fixed Service Fees*	40	40	40	40	40
Service Delivery Payments (Operations)	41	42	43	44	45
Ancillary Operations and Program Costs, outside of contract	19	19	20	20	20
Total additional cost per year	**100**	**101**	**103**	**104**	**105**

Source: Department of National Defence.

Notes: * Fixed Service Fees for each outyear are contractual and not indexed for inflation.

We assume the additional option years would begin in 2023-24; the current provision of service contract expires in late 2022-23.

Totals may not add due to rounding. Includes provincial taxes using an assumed rate of 9.975 per cent.

3.3. Foregone Purchase Option

The MV Asterix was offered for purchase upon its delivery to the Government of Canada in 2018 at a base price of $658 million, or $724 million with applicable taxes. This purchase cost does not include any operations and maintenance or ancillary program management costs.

In principle, the government could decide to enter discussions with Federal Fleet Services to purchase the Asterix at the conclusion of the initial 5-year lease period, where the price may be discounted to account for the shorter service life remaining on the vessel. If purchased at the expiry of the contract agreement in 2022-23, we estimate it will cost the government $576 million, or $633 million with tax. To arrive at this figure, we assume the Asterix had a 40-year lifespan from the time of its conversion, discounting its value linearly for each of the 5 contract years and estimating a residual end-of-life value of $3 million.[20]

Similar to our estimate of the JSS program, these purchase costs include only the acquisition of the ship and do not include any operations and maintenance or ancillary project costs.

The government has not indicated it will pursue the option to purchase the MV Asterix.

4. The Obelix

Chantier Davie Canada Inc. has offered the Government of Canada a second interim supply ship, the Obelix. This vessel is a near-identical sister ship to the pre-conversion MV Asterix, offering some savings in terms of shipyard experience and non-recurring design and engineering costs.

This section presents an independent estimate of the total project costs associated with the potential contracting of the Obelix, assuming a five-year initial contract period beginning in 2023-24 and ending in 2027-28.[21] We also develop an estimate for the one-time purchase cost assuming the option to purchase occurs on delivery in 2023-24.

4.1. Estimated Obelix Costs

As a relatively short period of time has elapsed since the conversion of the Asterix, we assume the reported costs are an appropriate basis upon which to base our estimates. These estimates account for increases in cost due to inflation and shipbuilding-specific cost escalation while incorporating potential savings from shipyard learning and lower design and engineering costs. We assume the terms of the contract are otherwise identical to those of the Asterix.

Table 4-1 presents a projected breakdown of costs associated with the potential 5-year contracting of the Obelix. The estimates were calculated separately for the fixed cost, variable cost, and non-contract amounts, and then distributed to the individual line items according to the percentage breakdown for the MV Asterix.

We estimate a total Obelix program cost of up to $801 million, including departmental contingencies. Of this amount: $489 million is attributed to fixed costs to be paid to the contractor; $215 million concerns variable operations costs; and $97 million for ancillary non-contract costs.

Table 4-1 Estimated Cost of Obelix Contracting

$ millions	**Cost**
Fixed Service Fee	427
Pre-Service delivery cost	43
Additional Work Requirements	19
Fixed Cost Subtotal	**489**
Service Delivery Payments (Operations)	158
Potential Additional Operations and Maintenance Costs	57
Variable Cost Subtotal	**215**

Ancillary Operations and Program Costs, outside of contract	97
Non-Contract Cost Subtotal	**97**
Total Potential Cost	**801**

Source: Department of National Defence.

Notes: Totals may not add due to rounding. Departmental cost contingencies included. Includes provincial taxes using an assumed rate of 9.975 per cent.

4.2. Obelix Purchase Option

Alternatively, the government could opt to purchase the vessel upon delivery in 2023-2024. For this scenario, we estimate a purchase cost of $797 million for the Obelix. This estimate is based on the prior option to purchase the MV Asterix while adjusting for cost escalation that has occurred since the 2017-18 fiscal year, less reductions in cost due to shipyard learning and the removal of non-recurring engineering and design fees. This estimated purchase cost does not include any operations and maintenance or ancillary program management costs.

In materials provided to the Parliamentary Budget Office, Chantier Davie Canada Inc. cited a potential purchase cost of $694 million, or approximately $763 million with applicable taxes, assuming completion of construction within the 2022 calendar year.[22]

5. Cost Comparison of the JSS, Asterix and Obelix

This section compares the cost of the JSS program with the costs of the MV Asterix and Obelix replenishment vessels.

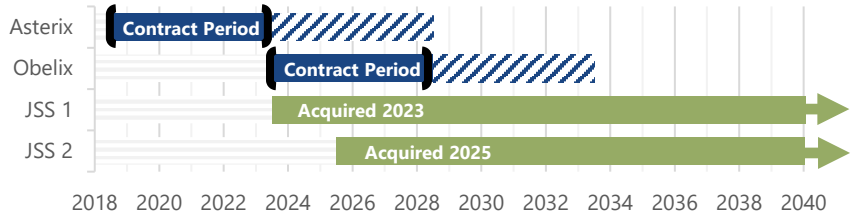
Difficulties in Comparing JSS Procurement Costs and Asterix Contract Costs

A straightforward comparison of the costs associated with the JSS and the Asterix programs in their current form is complicated by several factors. We highlight two issues in particular:

1. Differences between the provision of service timelines of the Asterix and optional Obelix vessels and the projected in-service life of the Joint Support Ships; and,
2. The scope of the cost elements accounted for in the provision of service contracts of the Asterix and Obelix as compared to those included in the development and acquisition of the Joint Support Ships.

Figure 5-1 displays a comparison of the notional in-service profiles of the respective ships. The contracting arrangement of the Asterix has a fixed term of 5 years ending late in 2022-23, with additional one-year options for up to five years thereafter. We assume that a contracting of the Obelix would result in a similar profile beginning at the start of 2023-24. The fixed costs associated with the contracts of the Asterix and Obelix would therefore only provide a fixed term of usage for either ship. The costs associated with the Joint Support Ship acquisition project, meanwhile, would confer full ownership of the two vessels to the CAF, with the ships remaining in-service for their entire useful life.

Figure 5-1 Comparison of in-service profiles of the Asterix, Obelix, and JSS ships



Source: PBO calculations, Department of National Defence, Chantier Davie Canada Inc.

Note: For demonstration purposes, the deliveries and contract durations for each vessel is aligned to the midpoints of the indicated calendar years.

With respect to the cost elements accounted for in the contracting of the Asterix (and ostensibly the Obelix) vis à vis the Joint Support Ship project, the provision of service contract under which the Asterix operates accounts for a set of activities that include cost elements belonging to the in-service support phase of the vessel's life cycle. That is, operations and maintenance costs are included in the $733 million estimated project envelope. The reported Joint Support Ship project costs account only for all activities leading up to the delivery of the two ships to the CAF – project management, design and development, construction and testing – and does not include any costs relating to operations and maintenance.

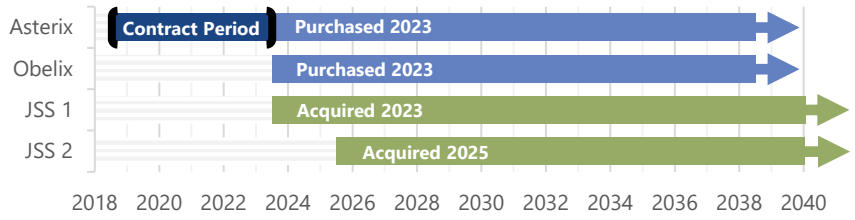
Comparing Asterix and Obelix purchase option costs to Joint Support Ship project costs

As the project costs of the JSS cannot be directly compared to the costs associated with the provision of service contract of the Asterix or any potential similar contract for the Obelix, we opt for a comparison of the JSS project to the cost of the purchase options for the Asterix and Obelix. Under this scenario, the issue of the fixed-term nature of the provision of service contracts for either the Asterix or the Obelix is obviated as the ships would be owned by the government until disposed at the end of their service life. Further, the operations and maintenance costs associated with either the Davie or JSS vessels can be left outside the equation, allowing for a comparison of project acquisition costs.

Figure 5-2 displays the in-service profiles of the two Davie vessels under this purchase scenario alongside the presumptive delivery and in-service profile of the two JSS ships. In this scenario, the Asterix is purchased upon completion of its five-year provision of service contract at the end of the

2022-23 fiscal year, and the Government enters a purchase agreement for the Obelix within the 2020-21 fiscal year for delivery in line with the purchase of the Asterix, with a one-time payment occurring upon delivery.

Figure 5-2 Purchase Scenario: comparison of in-service profiles of the Asterix, Obelix, and JSS ships



Source: PBO calculations, Department of National Defence, Chantier Davie Canada Inc.
Notes: For demonstration purposes, the deliveries and contract durations for each vessel is aligned to the midpoints of the indicated calendar years.

Table 5-1 presents a comparison of the Asterix and Obelix purchase costs and the JSS project costs as stated by the Government of Canada.[23] The estimated cost of the Asterix, $633 million has been discounted from the initial purchase offer of $724 million as by the time of the purchase at the end of the 2022-23 fiscal year, the ship will have expended 5 years of its service life. Obelix costs are represented as calculated in Section 4.

Our calculations therefore suggest that the Asterix and Obelix replenishment vessels could be obtained by the Government of Canada for a total of approximately $1.4 billion, as compared to our estimated $4.1 billion JSS project cost.

Table 5-1 Comparison of Asterix and Obelix Purchase Costs and JSS Project Costs

$ millions	**Cost**
Purchase of MV Asterix	633
Purchase of Obelix	797
Asterix and Obelix Subtotal*	**1,430**
Joint Support Ship project** (2 ships) – main estimate	**4,053†**

Source: Department of National Defence and PBO

Notes: Totals may not add due to rounding. Departmental cost contingencies included in the Joint Support Ship estimate. Operations and maintenance costs are not included in these totals. There may be some disparity in these costs between the Asterix and Obelix vessels and the JSS.

* Includes provincial taxes using an assumed rate of 9.975 per cent.

** Includes provincial taxes using an assumed rate of 7 per cent, plus the PBO-calculated contingency of $631 million.

† Of the approximate $4.1 billion in expenditures associated with the JSS project, we estimate that over 1 billion has already been spent. As well, it is likely that the cancellation of the JSS project would incur a substantial amount of additional costs; PBO has not evaluated these additional costs.

Capabilities

An assessment of the capabilities of the Asterix and Obelix as commercial vessels converted for military purposes versus those of the built-for-purpose Joint Support Ship are outside the scope of this analysis.

Appendix A: JSS Primary Model

As explained in Section 2, this approach uses the cost per metric tonne of a similar ship as the base for our estimate, followed by several adjustments to account for the differences in construction costs and capabilities, to estimate the cost of the JSS.

PBO received the scheduled construction costs for the first T-AKE vessel constructed (T-AKE-1) from the CBO, which were distributed over the 2000 to 2007 United States fiscal years.[24] These USD costs include the cost of spares and taxes and are stated in then-year dollars. We deflate the costs to 2000-year dollars, using the Consumer Price Index (CPI) plus shipbuilding inflation for the United States (see Table A-1).[25] We sum these deflated costs to reflect the total cost of the ship, which we estimate at $615 million USD in real 2000-year US dollars.

To adjust for differences between the sizes of the T-AKE and the JSS classes, we divide the cost of the T-AKE-1 by its lightship weight (LSW), which was $21,455 USD per tonne in 2000-year dollars.[26] We multiplied this by the JSS LSW of 11,133 tonnes, producing our base estimate of $239 million in 2000-year USD.

We employ a learning curve approach to account for efficiencies gained through the production of the first Joint Support Ship, reducing the cost of the second in the production run. We estimate a learning rate of 91 per cent, meaning the cost of the second ship will be 91 per cent of the costs of the first ship.[27]

We then inflate the costs of each ship to 2020, reflecting the first year of major construction activity, using a custom index reflecting general inflation and shipbuilding-specific inflation (Table A-1).

Historically, shipbuilding inflation has consistently exceeded that of general inflation.[28] This has been deconstructed into two components, the first of which is the industry-specific inflation for these specific goods and services, which represents 1.2 to 0.9 per cent above general inflation. The second is a customer-driven factor termed "standards and requirements complexity", which contributed an additional 2.0 per cent annually.

The literature described standards and requirements complexity as the non-visible requirements, such as survivability, reaction time, pollution control, radar signature, and so on. We also refer to this as inflation for non-obvious capability improvements.

Table A-1 Shipbuilding index, 2000 – 2019

Calendar Year	US CPI growth	Shipbuilding inflation	Non-obvious capability improvements	Custom shipbuilding Index
2000	0.03	0.012	0.02	**1.00**
2001	0.03	0.012	0.02	**1.06**
2002	0.02	0.012	0.02	**1.12**
2003	0.02	0.012	0.02	**1.17**
2004	0.03	0.012	0.02	**1.24**
2005	0.03	0.012	0.02	**1.32**
2006	0.03	0.012	0.02	**1.41**
2007	0.03	0.012	0.02	**1.49**
2008	0.04	0.012	0.02	**1.60**
2009	0.01	0.012	0.02	**1.66**
2010	0.01	0.012	0.02	**1.73**
2011	0.03	0.012	0.02	**1.83**
2012	0.02	0.012	0.02	**1.93**
2013	0.02	0.012	0.02	**2.03**
2014	0.02	0.012	0.02	**2.12**
2015	0.00	0.012	0.02	**2.20**
2016	0.01	0.009	0.02	**2.29**
2017	0.02	0.009	0.02	**2.40**
2018	0.02	0.009	0.02	**2.52**
2019	0.02	0.009	0.02	**2.65**
2020*	-0.02	0.0045	0.01	**2.64**

Source: International Monetary Fund, CBO, Arena et. al.
Note: * Inflates from end of the US fiscal year 2019 (end of September 2019) to end of March, 2020 in order to align with the Canadian fiscal year ending 2020.

Once costs are escalated, we adjust for differences in ship capabilities and shipbuilding costs (including cost of labour, productivity and tax rates). Table A-2 presents the values of each of the key assumptions explained below.

Following Arena et al. (2006), we adopt the use of a power density differential to account for differences in ship capabilities. This approach entails multiplying the cost of the analogue ship by the amount of the differential to compensate for the additional costs associated with greater capabilities. The difference in power density, calculated as the kilowatt-hour per metric tonne, was a factor of 1.08. Assuming a linear relationship between ship capabilities and their cost, we estimate obtaining the JSS ship capabilities costs a premium of 8 per cent.

The cost of building identical ships in either Canada or the United States will be different as a result of differences in labour costs, labour productivity, and applicable tax rates. Labour costs and productivity differences will only

impact our estimate of the total labour costs of the JSS, which is estimated at 52% of the total JSS construction costs.[29] Taxes, on the other hand, apply to the total cost of construction.

We measure the difference in labour costs using total compensation per hour, which includes wages, salaries and employer social contributions.[30] To better reflect industry-specific differences, we calculate total compensation per hour for the US-termed "Other transportation equipment" industry, classified as the North American Industry Classification System (NAICS) 3364OT.[31] We estimate that in 2018, total compensation for US workers in the Other transportation equipment industry was $58/hour USD compared to $51/hour CAD for Canadian workers. Assuming the values for 2020 are equivalent to those in 2018, we therefore adjust the labour portion of the JSS cost downwards using a factor of 0.88.[32]

Productivity is measured as real gross domestic product (GDP) per hour.[33] Consistent with labour costs, we estimate productivity for the NAICS 3364OT in 2018 and use it as a proxy for the value in 2020. We estimate that in 2018, Canadian workers in this industry were less productive than their US counterparts by a factor of 0.57. Therefore, we adjust the labour portion of the JSS cost upwards by a factor of 1.75.[34]

To account for tax differentials, we use the difference in the provincial/state statutory tax rates for JSS shipyard of Vancouver in 2020 (7.0%) and the T-AKE shipyard in San Diego in 2000 (6.25%).[35] We therefore adjust the cost estimate upwards by a factor of 1.06.

We then convert the costs to $CAD using the average 2019-20 USDCAD exchange rate of 1.3306.[36]

Table A-2 Cost Adjustment Factors

	T-AKE	JSS	Factor	Source
Cost* ($ millions)	615.3	-	**-**	
LSW	25,803	11,133	**-**	CBO, DND
Learning Rate	-	91%	**-**	DND
Power Density†	1.38	1.50	**1.08**	CBO, DND
Compensation/ hour	58.25	51.25	**0.88**	U.S. Bureau of Economic Analysis: The Use of Commodities by Industries – NAICS 3364OT; U.S. Bureau of Labour Statistics: Multifactor Productivity – NAICS 3364OT; Statistics Canada Table: 36-10-0489-01 - NAICS 3366XX – 3369XX
Output/hour	101.15	57.44	**0.57**	Bureau of Labour Statistics, Bureau of Economic Analysis, Statistics Canada Table: 36-10-

				0434-03 – NAICS 3366XX – 3369XX; Statistics Canada Table: 36-10-0489-01 – NAICS 3364XX – 3369XX
Tax Rate	6.25%	7.00%	**1.0075**	Tax Policy Center - Sales Tax Statistics; California Department of Tax and Fee Administration - Forms and Publications; British Columbia – Provincial Sales Tax
2020 Currency Conversion	-	-	**1.3306**	PBO EFO

Notes: LSW – lightship weight, metric tonnes
* T-AKE costs represent 2000-year dollars. Calculated by deflating the costs provided by CBO using the custom shipbuilding index (See Table A-3).
† Power Density is calculated as kilowatt hours/LSW
Compensation refers to total compensation including wages and salaries and employer social benefits.
Output was measured as value-added at basic prices.

We then allocate the estimated real cost of each ship across the JSS fiscal year construction schedule according to the schedule provided by the Department of Defence. The projected amounts are inflated using PBO's projected CPI and adjusted for shipbuilding industry-specific inflation. According to the United States Congressional Budget Office, inflation in the shipbuilding industry is projected to outpace economic inflation by 0.9 per cent until 2020, and by 1.2 per cent thereafter.[37] We assume this phenomenon exists in the Canadian shipbuilding industry as well. Table A-3 presents projected CPI and assumed shipbuilding inflation from fiscal year 2020-21 to 2025-26.

In the final step, we adjust the point estimate to equal the 50th percentile in a Monte Carlo analysis that allows for variation in several of the key inputs used in the modelling process; Appendix B has further details.

Table A-3 Projected CPI and Shipbuilding inflation, 2020-21 to 2025-26

Fiscal Year	CPI (%)	Shipbuilding inflation (%)	Index
2020			**1.00**
2021	0.33	1.20	**1.02**
2022	1.38	1.20	**1.04**
2023	1.69	1.20	**1.07**
2024	1.92	1.20	**1.11**
2025	2.00	1.20	**1.14**
2026	2.02	1.20	**1.18**

Source: PBO Economic and Fiscal Outlook, CBO

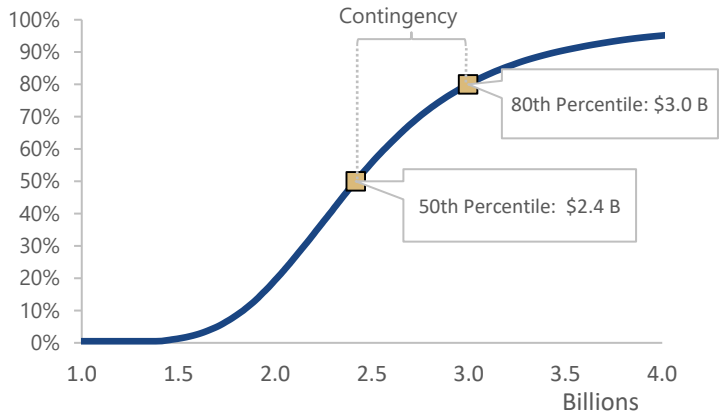
Appendix B: Monte Carlo Analysis

In order to account for modelling uncertainty, we conduct a Monte Carlo simulation that allows for variation in several of the key modelling inputs. In particular, we select the productivity and wage differentials between the United States and Canada; the estimated shipyard learning rate (91%); and the USDCAD exchange rate as inputs subject to uncertainty.

For productivity and wage differentials, we base the distribution on the historical variability in each of the two series. Variability in the shipyard learning rate is defined as a triangular distribution with a low of 0.86, a mode of 0.91 and a maximum of 1.0. The USDCAD variability is based on historical annual volatility in this series.

Figure B-1 presents the results of the resulting Monte Carlo simulation. We find a 50th percentile cost of $2.4 billion, consistent with our main estimate. The 80th percentile is $3.0 billion. To calculate contingency, we follow the United States Congress Weapons Systems Acquisition Reform Act of 2009, which suggests budgeting at the 80th percentile of a procurement project's cost distribution, and take the difference between this value and the 50th percentile. This yields an effective budgetary contingency of approximately $0.6 billion.[38]

Figure B-1 Cumulative Distribution of Construction Costs



Source: PBO calculations.
Notes: Figures rounded to the nearest $100 million.

Notes

1. The motion made on June 9, 2020 was "That the committee request that the Office of the Parliamentary Budget Officer undertake a costing analysis of building the Joint Supply Ship in Canada and leasing the Asterix and that the report containing this analysis be presented to the Chair of the committee by Thursday, October 15, 2020" url: https://www.ourcommons.ca/DocumentViewer/en/43-1/OGGO/meeting-18/minutes
2. While the federal tax on sales of goods and services would also be applied, they simultaneously represent a source of revenues for the federal government.
3. As described in Section 2, our cost estimate of the JSS program includes our independent estimate of construction costs, combined with the government's stated non-construction project costs and our calculated contingency.
4. See project name "Joint Support Ship" at url: https://www.canada.ca/en/department-national-defence/corporate/reports-publications/departmental-plans/departmental-plan-2020-21-index/supplementary-information-index/report-crown-projects.html#JSS, last updated March 10, 2020.
5. Department of National Defence, *Reports on Plans and Priorities* 2007-2008.
6. Procurement Services and Procurement Canada, *News Release*, "Government of Canada awards contract for construction of joint support ships for Royal Canadian Navy", June 15, 2020. url: https://www.canada.ca/en/public-services-procurement/news/2020/06/government-of-canada-awards-contract-for-construction-of-joint-support-ships-for-royal-canadian-navy.html
7. Government of Canada, Department of National Defence web page, "Joint Support Ship", Project phase 4: Implementation, last updated December 3, 2018, url: https://www.canada.ca/en/department-national-defence/services/procurement/joint-support-ship.html
8. It is worth noting that while the arrangement with Chantier Davie Canada Inc. is often referred to as a 'lease', it is in fact a Provision of Service contract.
9. 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
10. Arena, Mark V., Irv Blickstein, Obaid Younossi, and Clifford A. Grammich. "Why Have Navy Ship Costs Risen?." (2006). url: https://www.rand.org/content/dam/rand/pubs/monographs/2006/RAND_MG484.pdf
11. Specifications were collected from the Naval Vessel Register. url: https://www.nvr.navy.mil/SHIPDETAILS/SHIPSDETAIL_AKE_1.HTML, last

updated March 6, 2020. Accessed September 3, 2020. CBO provided the cost breakdown over time.

12. Department of National Defence response to PBO Information Request IR #0501, 2020, url to response: https://www.pbo-dpb.gc.ca/web/default/files/Documents/Info%20Requests/2020/IR0501_reply_en.pdf
13. All weights are given in metric tonnes unless otherwise noted.
14. Arena, Mark V., Irv Blickstein, Obaid Younossi, and Clifford A. Grammich. "Why Have Navy Ship Costs Risen?." (2006). url: https://www.rand.org/content/dam/rand/pubs/monographs/2006/RAND_MG484.pdf
15. It is worth noting that the costs from a delay will vary dependent on when in the construction schedule they occur. Often, certain costs are fixed after an agreement or negotiation, making them less vulnerable to shifting timelines.
16. Department of Defence, *Backgrounder*, "Understanding the cost of the Joint Support Ship project", June 15, 2020. url: https://www.canada.ca/en/department-national-defence/news/2020/06/backgrounder---understanding-the-cost-of-the-joint-support-ship-project.html
17. Department of Defence, *Backgrounder*, "Understanding the cost of the Joint Support Ship project", June 15, 2020. url: https://www.canada.ca/en/department-national-defence/news/2020/06/backgrounder---understanding-the-cost-of-the-joint-support-ship-project.html
18. Department of National Defence response to PBO Information Request IR #0501, 2020, url to response: https://www.pbo-dpb.gc.ca/web/default/files/Documents/Info%20Requests/2020/IR0501_reply_en.pdf
19. Chantier Davie Inc. is located in the province of Quebec, therefore we assumed the applicable tax is Quebec's provincial sales tax of 9.975 per cent. We were unable to account for any potential tax refunds. See Revenue Quebec, Basic Rules for Applying GST/HST and QST. url: https://www.revenuquebec.ca/en/businesses/consumption-taxes/gsthst-and-qst/basic-rules-for-applying-the-gsthst-and-qst/#:~:text=The%20most%20common%20consumption%20taxes,selling%20price%20excluding%20the%20GST. Accessed September 21, 2020.
20. Officials from the Department of National Defence have asserted that the Asterix has a remaining life of approximately 16 years; Davie officials have indicated that the Asterix has a remaining life of up to 40 years from the time of conversion in 2018, citing instances of other converted replenishment vessels that have remained in service for other militaries for similar periods. See, for instance, the US Algol-class fast sealift ships. Eight of these ships were built as commercial container vessels in the early 1970s and were converted for military purposes in the 1980s. All eight are still in service with the US Navy as of 2020.
21. The delivery of the Obelix could occur as early as the 2022-23 fiscal year, depending on how soon the Government of Canada enters into an agreement with Chantier Davie Canada Inc. A 2023-24 delivery assumes this agreement is reached at the start of the 2021-22 fiscal year.

22. Official communication to the Parliamentary Budget Officer from Chantier Davie Canada Inc., August 18, 2020.

23. The full JSS project cost is used as the purchase cost of the Asterix and Obelix would implicitly include cost elements outside of construction costs, such as design, engineering, and project management costs.

24. In contrast to the Canadian government's fiscal year that runs from April to March, the United States government's fiscal year begins in October and ends in September.

25. For CPI: International Monetary Fund, International Financial Statistics, Consumer Price Index, All Items. url: https://data.imf.org/?sk=4c514d48-b6ba-49ed-8ab9-52b0c1a0179b Accessed: July 29, 2020. For Shipbuilding inflation: 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

26. The lightship weight of the T-AKE-1 was converted from long tonnes to metric tonnes.

27. Our assumed 91 per cent learning rate relies on the anticipated learning rate from DND. Source: Department of National Defence response to PBO Information Request IR #0501, 2020, url to response: https://www.pbo-dpb.gc.ca/web/default/files/Documents/Info%20Requests/2020/IR0501_reply_en.pdf

28. See CBO "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 and Arena, Mark V., Irv Blickstein, Obaid Younossi, and Clifford A. Grammich. "Why Have Navy Ship Costs Risen?." (2006). url: https://www.rand.org/content/dam/rand/pubs/monographs/2006/RAND_MG484.pdf

29. Department of National Defence response to PBO Information Request IR #0501, 2020, url to response: https://www.pbo-dpb.gc.ca/web/default/files/Documents/Info%20Requests/2020/IR0501_reply_en.pdf

30. Canada's supply-use tables were only available up to 2016. However, Statistics Canada had comparable tables providing the total compensation by industry. We compared the 2016 values in these tables to the values in the supply-use tables, and found a minor difference of less than 0.3 per cent. We therefore felt confident in using the tables from Statistics Canada for total compensation.

31. Other transportation equipment is comprised of NAICS 3364XX (Aerospace product and parts manufacturing), 3354XX (Railroad rolling stock manufacturing), 3366XX (Ship and boat building) and 3369XX (Other transportation equipment manufacturing) where 'X' indicates all industry codes within this 4-digit code.

    PBO attempted to estimate the labour cost for NAICS 3366XX (Ship and boat building) explicitly, however several factors made this option less reliable. For one, US data for this NAICS was only available for 2007 and 2012, making any projections or comparisons for more recent years problematic. Second, corresponding data for Canada in 2012 coincided with the beginning of significant investment in shipbuilding. We believe the

Canadian data for this year would not be representative of a typical year of labour costs, productivity or shipbuilding learning. For this reason, we opted to use the next-highest level of aggregated to approximate the data for the shipbuilding industry.

We used data for 2018 – the most recent year for which data was available in both the US and Canada.

32. Currency conversion is not required as the Unit Labour Cost is calculated as the ratio of the compensation in the national currency divided by real output in the national currency.

33. Canadian GDP by Industry is presented at basic prices, whereas the US reports market prices. PBO used the gap between Canada's total GDP (market prices) and Canada's total GDP for all Industries (basic prices) to adjust the industry-specific GDP to reflect market prices. Chained (2012) GDP were used for both nations, with Canadian GDP converted to USD purchasing power parity (PPP) using a PPP index. The index is available here: OECD (2020), Purchasing power parities (PPP) (indicator). doi: 10.1787/1290ee5a-en (Accessed on 04 October 2020)

34. This is equivalent to one over 0.57.

35. 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.

36. Calculated using the PBO's Economic and Fiscal Outlook model.

37. Projected CPI is consistent with PBO's Economic and Fiscal Outlook model, as at August 31, 2020.

38. United States Congress, Weapon Systems Reform Act of 2009, Public Law 111-23, 111th Congress. url: https://www.congress.gov/111/plaws/publ23/PLAW-111publ23.pdf