


**Review of the Parliament Budget Officer Report: “An Estimate of the Fiscal Impact of Canada’s Proposed Acquisition of the F-35 Lightning II Joint Strike Fighter”**

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**Dissemination**

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**The review presented in this document considers only the methodology used to produce the cost estimates in the Parliament Budget Officer (PBO) report.**

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	<b>REVIEW OF PBO REPORT'S COST ESTIMATING METHODOLOGY</b>			Issue: 1.0	Date: 18/03/2011
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## 1. INTRODUCTION

The PBO report was produced on 10 March 2011 in response to a request from Members of Parliament (MP) in relation to the Government's proposed acquisition. The request was in two parts. The first asked the PBO to identify the premium Canada might pay as a result of the decision to procure aircraft from one source (otherwise known as sole-sourcing) rather than run a competition among potential suppliers. The second was a request to provide an independent forecast of the acquisition and sustainment costs<sup>1</sup> of the F-35.

**The review presented in the following section concentrates solely on the methodology used in the PBO report to calculate the costs associated with the second part of the MP's request, that is, the estimate of acquisition and sustainment costs of the F-35.**


## 2. REVIEW

It appears that the authors of the PBO report have tried to structure their arguments as best as they could in order to produce objective cost estimates. However, after a careful examination, a number of questions have arisen with regard to the methodology used to produce the results. These are as follows:

1. The authors have not stated explicitly the justification for some major assumptions: The JSF program has been in development for over a decade, and is now entering initial production phase. In spite of this, the chosen approach to cost estimation has been to apply parametric, as opposed to factorial or more detailed estimating methods. Parametric methods are indeed fast and are usually used at early design (feasibility study) stages. However, they are not particularly accurate, even when based on a wealth of historic data, due to changing technology, market conditions, cost/risk sharing arrangements, and so forth. As the authors themselves point out on p. 24: *"The empirical strength offered by focusing on trends is counterbalanced by a key limitation: the analysis is historical. This means that it is possible that the F-35A constitutes an outlier, in that its cost might be significantly different relative to what the historical trend would suggest."*
2. Very little is disclosed about the scope, assumptions and inter-relationships (e.g., cost estimating relationships and correlations) behind the cost model which is employed to produce the forecast of US\$ 128.8 million for the program average F-35A unit acquisition cost over the entire program (see pp. 26-27). Even if one accepts the graph on p. 27, it is unclear why the authors refer to the 50<sup>th</sup> percentile. The accuracy range should be calculated from (at least) the 70% confidence range<sup>2</sup>, covered by the 15% and 85% points on the cumulative probability distribution. Using the graph on p.27, this would give only about [-20, +30]%

<sup>1</sup> The PBO report states that on 16 July 2010, the Government of Canada announced its intention to acquire 65 F-35 Lightning II Joint Strike Fighter (JSF) aircraft for an estimated C\$ 9 billion, with maintenance and support costs estimated at C\$ 250–300 million per year. These figures have been reported to result in a total ownership cost for the program of approximately C\$ 16–18 billion.

<sup>2</sup> BP Engineering Risk Analysis Group. Cost Risk Analysis BRISK Manual, British Petroleum Engineering, April 1989.

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accuracy range of the forecast, again, only if one accepts that the cost model is to be trusted. With this respect, the statement on P.27: *"In this case the input values represent higher than historical data average. So, this is saying the F-35 input variables are above the historical average for strike/fighter jets."*, leaves room for explanation.


3. The construction of the learning curve (p.28) begs a few questions:

- It appears (see footnote 60 on p. 28 of the PBO report) that the graph on p.28 was constructed using 3 points. How is this justified to be sufficient? There are a few more points with values specified on the curve, but it is not explained where these come from. It is not clear how the cost of the 1-st Unit was estimated. It is not explained why the proposed learning curve should be more accurate than the learning curves used in practice. Here it needs to be emphasized that aircraft production typically follows 75-85% learning curves<sup>3</sup>. A rather conservative estimate is illustrated in Table 1 with learning curves varying between 80-90%. The first unit cost is assumed \$367M and is taken from the learning curve on p. 28 of the PBO report. A few iterations reveal that the closest match is approximately 89.78% learning curve. Such value is way above the quoted in the literature for aerospace, as mentioned above.

Learning %	Cost of First Unit [\$M]	Cumulative Average cost of the 848-th Unit [\$M]	Cost of the 848-th Unit [\$M]	Cumulative Average cost of the 2478-th Unit [\$M]	Cost of the 2478-th Unit [\$M]	Method used	
?	367	148.5	?	128.8	?	? PBO report	
						Wright	Crawford
90	367	131.7	111.7	111.9	94.9	■	
90	367	155.1	131.7	131.9	111.9		■
89.78	367	128.6	108.6	108.8	91.9	■	
89.78	367	152.1	128.6	128.9	108.8		■
85	367	75.5	57.8	58.7	45.0	■	
85	367	98.4	75.5	76.7	58.7		■
80	367	41.9	28.4	29.6	20.1	■	
80	367	61.4	49.9	43.7	29.6		■

**Table 1 : Learning Curves comparison; Figures are rounded up to first decimal point.**

<sup>3</sup> See, for example Raymer, D.P., Aircraft Design: A Conceptual Approach, AIAA, 1992, ISBN 0-930403-51-7; or NASA's Cost Estimating web site: <http://cost.jsc.nasa.gov/learn.html>

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- On p. 27 of the PBO report the authors state: *“According to the Program Office’s forecasts, by the time Canadian deliveries begin, a maximum of 330 aircraft will have been manufactured and delivered; by the time Canada takes the last delivery, a maximum of 1,367 F-35As will have been manufactured and delivered to US and international purchasers. The midpoint of these values is 848 ”*. Then the authors use this value, as shown in the learning curve on p.28, to obtain the value of \$148.51M for the cumulative average unit acquisition cost. This strongly suggests that the authors assume that the average unit cost will depend on the time of delivery rather than on some agreed cost. This point certainly needs clarification [N.B. The author of this review is not aware of the details of the Canadian contract].

### 3. CONCLUSIONS

I do not have reasons to doubt the integrity of the authors of the PBO report or their good intent. However, after examining the report, I believe that some of the assumptions and the methodology used to produce the estimates are questionable. I would strongly recommend a further investigation.