OFFICE OF
THE PARLIAMENTARY BUDGET OFFICER

CANADA

BUREAU DU
DIRECTEUR PARLEMENTAIRE DU BUDGET

Cost Estimating Canada's Surface Combatants (CSC)

Rod Story

Brief PBO Background

- The Parliamentary Budget Office (PBO) provides public, independent, & detailed financial information to Members of Parliament and Canadians similar to Congressional Budget Office (CBO) in the U.S.
- Budget = $2.8 million
- Size = currently 17 including people on contract, students and 2 admin

Functions of the PBO

- Economic & Fiscal Analysis
  - E.g. Fiscal Sustainability Report, Economic and Fiscal outlook, federal budget analysis etc.
- Expenditure & Revenue Analysis
  - Research into the government's estimates and annual spending (Estimates Monitor)
  - Costing of Government and Private Member's Bills
    - Costing of things like ships, airplanes, disasters, marijuana, bridge tolls, first nation schools, etc.

Some definitions

- What is a frigate today?
  - Approximately 6,000 tonnes or less full load
  - anti-submarine warfare with limited air warfare capability (radar – 200 km, fewer targets)
  - 32 or less vertical launch system (VLS) cells
- What is a destroyer today?
  - Approximately 7,000 tonnes or more full load
  - Air warfare 3D radar, 1000+km, 1500+ targets
  - 48 or more VLS cells

Costs of destroyers/frigates

- Arleigh Burke (DDG 51)
  - Flight IIA =$1.73B US in FY14$ (FY18 deliver)
    - add approximately $200M if Flight III with bulk of cost difference for new radar
  - 9,800 tonnes full load, 165m
- Australian Hobart $9.2B AUS for three ships
  - then year dollars from 2008 to 2018 including fixed costs - $2.3B US/ship(current exchange rate) ($3.1B US/ship at 2008 exchange rate)
  - 147m, 7,000 tonnes full load

Why are naval ships so expensive?

- 2006 RAND report
  - They have been increasing in:
    - Weight and Length
      - 1972 Iroquois destroyer = 5,200 tonnes, 129m
      - 1992 Halifax frigate = 4,600 tonnes, 134m
      - Current frigates and destroyers = 7,000 tonnes, 150m
    - Complexity
      - 3D radar (Active Electronically Scanned Array – AESA)
      - Combat system integration and reduced manpower
      - Co-operative engagement capability (CEC)
        - Networking of ships – think Transformers! (kid's toy)

Why are naval ships so expensive?

- Non-obvious capability increases
  - Survivability
  - Reaction time
  - Reliability and maintainability
  - Endurance (how long ship can stay at sea without replenish)
  - Habitability (more space per sailor)
  - Radar and noise signatures (stealth)
  - Regulations (e.g. waste disposal, safety standards)
- Overall, RAND found that all else equal:
  - Weight and complexity each cause a linear increase in cost (double weight and complexity = 4 times the cost)
  - 2%/year for non-obvious capability increases
  - GDP inflation plus 0.4%

Why are naval ships so expensive?

- Additional cost drivers
  - Congressional budget office (CBO) has found that inflation for naval purchases (same ship but at a later date) is on average 1.2% greater than GDP inflation.
    - Due to the labor and material basket for ships being different than either GDP or CPI, ships experience a higher inflation rate

Indigenous shipbuilding premium

- Estimated premiums for indigenous shipbuilding
  - RAND 2015 report on Australia
    - 40% premium though sensitive to exchange rate
      - Exchange rate has since decreased, decreasing labor premium but increasing foreign equipment e.g. AEGIS weapon system
  - Canadian exchange rate example
    - Canada/US ratio hourly compensation cost for manufacturing was 1.03 in 2012 and was 0.78 in December 2016 due to decline in Canadian dollar

Indigenous shipbuilding premium

- Canadian exchange rate example continued
  - For ship welders wage ratio (CDN/US) was 1.5 in 2012 and 1.14 now due to decrease in Canadian dollar
- Australian Strategic Policy Institute (ASPI) 2012
  - Found Hobart program approximately 23% above marginal cost of Arleigh Burke in 2012 (exchange rate was at par)
  - In 2017, Hobart 33% above marginal cost of an Arleigh Burke (earlier slide)
    - Combination of cost overruns and currency decline
  - Hobart is almost 30% smaller than an Arleigh Burke

Cost Estimating Methods

- Three separate methodologies used
  1. Ship costing heuristics via RAND 2006 (Why Has the Cost of Navy ships risen?)
  2. Ship costing heuristics via RAND 2015 (Australia's Shipbuilding Enterprise)
  3. Parametric cost modeling software
- Base information was the Canadian Patrol Frigate (CPF) program from 1983 to 1996
  - First ship in class was the Halifax and primary purpose was anti-submarine warfare

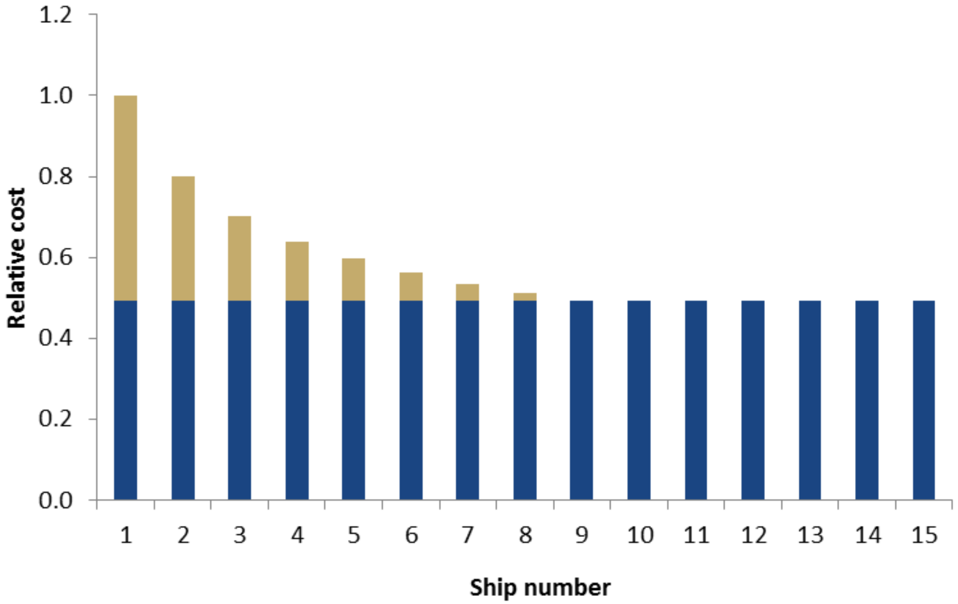
Overview of CPF program

- Canadian Patrol Frigate (CPF) program

	Cost billions FY2017 $
Program start	Late 1970s
Implementation contract signed	1983
First ship delivered	1992
Last ship delivered	1996
Total program cost for 12 ships	$8.86 billion
NATO sail-away costs for 12 ships	$5.28 billion
Cost of spares beyond 2 years	$866 million
Government project management	$382 million
Facilities, training & documentation	$324 million
Fixed costs, development, ammunition	$2.01 billion

80% Learning Curve

- Over 15 ships, learning adds 16% in cost
- Learning is done by 9th ship



Cost Estimating Methods Detail

- RAND 2006
  - From earlier slide 2% per year for non-obvious capability growth
  - Multiply by % increase in complexity and weight
    - Proxy for complexity is kilowatts per tonne
      - As number of s/w systems, complexity of radar, and integration increases, so does the electricity required
  - Increase by GDP inflation +.4% between programs
  - GDP Inflation plus 1.2%* when in program
  - Use cost of 9th ship since end of learning

*Note: PBO change based on CBO findings

Cost Estimating Methods Detail

- RAND 2015
  - Take the cost of the ship to build in the originating country, convert to local currency, inflate by GDP plus 1.2%* to current year (extra in-production inflation), adjust cost base on LSW, and then account for labour efficiency
    - Assuming labor efficiency is the same, Canada's wages are 1.14 more expensive (earlier slide)
    - In the mid-1990s (i.e. end of CPF program) Canada-US shipbuilding costs were similar based on dollars per tonne of ship. Still holds with lack of experience?

*Note: PBO change based on CBO findings

Cost Estimating Methods Detail

- Parametric cost modeling
  - Used PRICE cost modelling software (S/W)
  - Was tested on 8 sample NASA projects and was within +/- 20%.
  - Input all the data from the original CPF program then used the S/W to estimate the complexity of the ship's 7 structural components
    - Hull, propulsion, electric, command and surveillance, auxiliary systems, outfit and furnishing, and armament

Cost Estimating Methods Detail

- Parametric modeling continued
  - Once CPF modeled in S/W using concept of manufacturing complexity, basic parameters (weights, labour costs, inflation, delivery dates) were modified to CSC specification to determined estimated cost of CSC
  - Needed to determine an inflation/escalation rate for MOTS combat systems
    - A rate of 6.5% was used based on RAND 2006
  - All other inflation was GDP inflation+1.2% (CBO)

Combat system inflation rate

- Combat system inflation based on RAND 2006
  - 2.1% annual inflation due to LSW and power density increase
  - Using equations in paper to determine 1.1 percentage points due to power density increase
    - Assume this to be all combat system
  - 1.1% is for total ship cost but becomes 4.1% when applied only to combat system
  - Add GDP inflation (2%) plus RAND 0.4% above GDP = 6.5%

Methodology Results

- RAND 2006 methodology using CPF costs
  - 9th CPF cost $390M in FY1994
  - Need to account for 2% due to non-obvious
    - Period is from first ship to first ship, but report only covered to 2004. Unsure if valid beyond. Stop at 2004.
    - First CPF is 1991, so deflate by 3 years at 3.2%=$355M
    - 2% for non-obvious to 2004 = $459M
  - CPF used 1.7 mw and weighed 3748t lightship weight (LSW) for 0.454 kw/t

Methodology Results

- RAND 2006 method continued
  - PBO selected a ship from competing designs for CSC LSW and power density (Italian FREMM)
    - 5400t LSW and power of 2.8 mw
    - Need to add .5 mw for north Atlantic cold, results in 3.3 mw (3300kw/5400t = 0.61 kw/t)
  - 0.61 kw/t for CSC or an increase by 1.35
  - CSC LSW of 5400t & CPF was 3807t for an increase in LSW of 44%
  - 1.44weight*1.35power*$459 = $892M in 1991

Methodology Results

- RAND 2006 method continued
  - Now inflate the $892M to 2017 by GDP inflation plus 0.4% (2.4%) to get $1,653M
  - Need to account for the tax difference between the two time periods (6.1% effective rate before and now 15%)
    - 1,653 * 1.089 = $1,800M in FY2017

Methodology Results

- Variation of RAND 2015 method
  - Estimate of 9th Arleigh Burke IIA at Huntington Ingalls shipyard in FY2014 $1.42B US
  - Inflate to 2017 by CBO in program inflation of GDP inflation plus 1.2% (3.2%) = $1.57B US
  - Convert from US to CAD at 1.33 = $2.09B CAD
  - Since Arleigh Burke light-ship weight is 7190t and CSC is 5400t, scale cost down by .75 (5400/7190) = $1.57B CAD

Methodology Results

- RAND 2015 method continued
  - Using 14% labour premium (labour 31% of cost of 9th ship).
    - Therefore, 1.57*(0.31*1.14 + 0.69) = $1.64B CAD
  - These costs assume 9th ship cost with prior ships costing more due to learning curve.

Parametric cost model

- Parametric modeling allows for the inclusion of the total program costs. For example:
  - Learning curve
    - Previous estimates assume 9th ship, so at the end of the unit learning curve
    - Learning curves for shipbuilding are around 84%
      - CPF had a labour learning curve of 73%
      - Considered a "dumb" shipyard since was inexperienced
    - Arleigh Burke has an overall learning curve of 93%
    - CSC model used 80% learning curve based on experience building ships but not surface combatants

Parametric cost model continued

- Other items included in Parametric cost model
  - Fixed costs
  - Government management, training, and facilities
  - Inflating different components of the ship at different rates
  - Updated labor rates

Parametric cost model continued

- Parametric modeling enables analysis of:
  - % of Canadian versus non-Canadian content
  - Labour hours by component and by ship number
  - Cost of 1st and last ship
  - Sensitivity analysis for schedule and other changes
  - "What if" analysis for informed decision making
  - Costs in both nominal and real dollars

Parametric results

	CSC cost in billions $ (FY2017 $)	CSC cost in billions $ (then-year $)
Total Program Cost	39.94	61.82
Average ship cost	1.66	2.73
Total development cost	4.53	5.10
Total production cost	27.82	45.23
Spares for 2 years	0.83	1.31
Spares for remaining years	4.42	6.96
Ammunition	0.98	1.54
Facilities	0.16	0.18
Documentation	0.07	0.08
Training	0.26	0.38
Government program management	0.88	1.05

Results comparison

	Parametric	RAND 2006	RAND 2015
9th ship cost	$1.59B CAD	$1.8B CAD	$1.64B CAD

- Comparing the three cost estimates, they are all within the +/- 20% margin. If anything parametric is maybe too low.
- Estimated that the Government is paying a 25% premium for building the ships in Canada
- Get the full report on the PBO website.