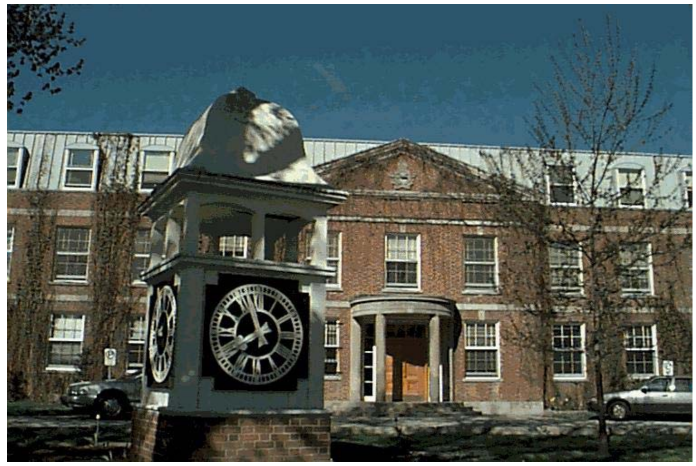
National Defence Défense nationale

Canadian Forces College

Collège des Forces Canadiennes



SHRINKING FLEETS: AN RCN FEASIBILITY STUDY INTO ALLIED COST-SAVING STRATEGIES

LCdr M.M. Majdoub

JCSP 41

PCEMI 41

Master of Defence Studies

Maîtrise en études de la défense

Canada

CANADIAN FORCES COLLEGE – COLLÈGE DES FORCES CANADIENNES
JCSP 41 – PCEMI 41
2014 – 2015

MASTER OF DEFENCE STUDIES – MAÎTRISE EN ÉTUDES DE LA DÉFENSE

SHRINKING FLEETS: AN RCN FEASIBILITY STUDY INTO ALLIED COST-SAVING STRATEGIES

By LCdr M.M. Majdoub

Word Count: 20669

Compte de mots : 20669

Table of Contents

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

ADSI	Air Defence Systems Integrator
AOPS	Artic Offshore Patrol Ship
AOR	Auxiliary Oiler Replenisher
ASuW	Anti-Surface Warfare
ASW	Anti-Submarine Warfare
AWACS	Airborne Early Warning and Control System
C2AD	Command and Control Air Defence (CSC Variant)
CAD	Canadian Dollar
CAF	Canadian Armed Forces
CAS	Close Air Support
CBO	Congressional Budget Office
CEC	Cooperative Engagement Capability
CEMP	Capacité d’Engagement Multi Plate-forme
CF	Canadian Forces
CFC	Canadian Forces College
CFD	Chief of Force Development
CFDS	Canada First Defence Strategy
CJOC	Canadian Joint Operations Command
CMS	Chief of Maritime Staff
COA	Course of Action
CORA	Center for Operational Research and Analysis
CPF	Canadian Patrol Frigate
CRS	Congressional Research Service
CSBA	Center for Strategic and Budgetary Assessments
CSC	Canadian Surface Combatant
CSL	Combat Ship for the Littoral
DDG	Guided Missile Destroyer
DGA	Délégation Générale pour l'Armement (France)
DM	Distributed Margins
DMC	Distributed Modular Construction
DND	Department of National Defence
DRDC	Defence Research and Development Canada
DWP	Docking Work Period
EMC	Expeditionary Maintenance Capability
ERP	Enterprise Resource Planning
EU	European Union
FFG	Guided Missile Frigate
FOC	Full Operational Capability
FREMM	Frégate Européenne Multi-Mission

GCS	Global Combat Ship (Type 26)
GDI	Global Competiveness Index
GDOTS	General Dynamic Ordinance and Tactical Systems
GFE	Government Furnished Equipment
GP	General Purpose (CSC variant)
HCM	Halifax Class Modernization
HMCS	Her Majesty's Canadian Ship (Canada)
IOC	Initial Operational Capability
IRO	Iroquois Class Destroyer
ISI	Irving Shipbuilding Inc.
ISIL	Islamic State of Iraq and the Levant (group)
ISO	International Organization for Standardization
ISS	In-Service Support
JCSP	Joint Command and Staff Programme
JDAM	Joint Direct Attack Munition
JOPG	Joint Operations Planning Group
JSS	Joint Support Ship
LCS	Littoral Combat Ship
LHD	Landing Helicopter Dock (ship)
LOO	Line of Operation
LPD	Landing Platform Dock (ship)
MCDV	Maritime Coastal Defence Vessel (Canadian Navy)
MCM	Mine Counter Measure
MEKO	TKMS brand of Ships
MH	Maritime Helicopter
MLB	Modular Langsbaukasten (VW strategy)
MN	Marine National
MOTS	Military Off the Shelf
NATO	North Atlantic Treaty Organization
NAVSEA	Naval Sea Systems
NCW	Network Centric Warfare
NDHQ	National Defence Headquarters
NGFS	Naval Gun Fire Support
NGSB	Northrop Grumman Ship Building
NORAD	North American Aerospace Defense Command
NORCOM	Northern Command
NRL	Naval Research Laboratory
NRV	Naval Research Vessel
NSPS	National Shipbuilding Program Strategy
OA	Options Analysis
OEM	Original Equipment Manufacturer/Manufacturing
OPCYCLE	Operational Cycle

OPNAV	Operational Naval Staff
OPV	Offshore Patrol Vessel
PM	Preventative Maintenance
PMO	Project Management Office
PPB	Pacific Patrol Boat
RAN	Royal Australian Navy
RCAF	Royal Canadian Air Force
RCN	Royal Canadian Navy
RDN	Royal Danish Navy
RF	Radio Frequency
RIMPAC	Rim of the Pacific
RN	Royal Navy
ROI	Return On Investment
SAM	Surface-to-Air Missile
SC	Scalable Commonality
SDSR	Strategic Defence Security Review
SEWIP	Surface Electronic Warfare Improvement Program
SME	Subject Matter Expert
SOR	Statement of Requirements
SPS	Southern Partnership Stations
SSK	Submarine Conventional
STANFLEX	Standard Flex
STW	Set-to-Work
SWP	Short Work Period
TEWMP	Transportable Electronic Warfare Module Program
TKMS	Thyssen-Krupp Marine Systems
TRANREQ	Transfer Requirement
TRL	Technology Readiness Level
UAV	Unmanned Air Vehicle
UGV	Unmanned Ground Vehicle
UK	United Kingdom
US	United States
USAF	United States Air Force
USD	United States Dollar
USN	United States Navy
USS	United States Ship
USV	Unmanned Surface Vehicle
UUV	Unmanned Underwater Vehicle
UV	Unmanned Vehicle
VW	Volkswagen

ACKNOWLEDGMENTS

I would like to extend my sincere thanks and gratitude to the following individuals who have supported me throughout this process: Dr Craig Stone, my thesis advisor, for his steadfast supervision and direction; Dr Kenneth Hansen, a strategic maritime research fellow at Dalhousie University, for his insightful guidance on past and present naval strategy; The entire Directorate of Naval Strategy team including Commander Barb McIntyre, Dr Lombardi and Dr Mirshak for their unrelenting support and advice; Capt(N) Casper Donavan, former Director of Naval Strategy, for his mentorship at the onset of this project; Commander Hughes Canuel, staff at the Canadian Forces College, for helping me shape and refine my arguments; and most importantly my wife Marija Majdoub for holding down the fort and keeping me focused.

ABSTRACT

Rising ship costs are forcing allied naval planners to seek alternative approaches to achieving and maintaining maritime security. Rapid advances in technology have enticed planners to try and keep pace with emerging capabilities to the detriment of spiralling cost. Unfortunately public funding has not matched the increased demand. The net result has caused a reduction in platforms rather than capabilities. Worldwide allied fleet sizes have decreased on average by 40% since the end of the Cold War. Current ship building costs are outpacing inflation by a mean 9%. The continued allied trend towards shrinking fleets will remain if shipbuilding inflation rates are left unmitigated. Fortunately there is a renewed awareness by western navies and a dramatic shift in their force employment, sustainment and procurement strategies.

The overall intent of this research paper is to conduct a Royal Canadian Navy (RCN) feasibility study into allied cost-saving strategies. The analysis examines common allied trends in cost-saving measure, mitigating strategies and evolved operational structures that compensate for the decline in platforms. Each allied cost-saving strategy is applied to the Canadian context in order to evaluate which ones should the RCN adopt. The results indicate that a majority of the cost-saving strategies under study are applicable to the RCN but that they cannot be adopted in isolation. The inter-dependencies between these strategies necessitate careful phasing and synchronization in order to yield significant savings. The net result is a potential 50% increase in platforms, most of which are only applicable to new builds. Consequently new builds need not only focus on capabilities they bare but the life-cycle stories they intend to live out. The paper surmises that cost must be adopted as a strategy and that by distributing effort, significant savings can occur.

INTRODUCTION

BACKGROUND

> In "The Treaty Navy, 1919-1937," historian Philip T. Rosen argued that the naval innovations of the interwar years were, at least to some degree, an adaptive response to restrictions imposed on the Fleet by the naval-arms-limitation treaties of the 1920s. An analogous argument might be made about the potential for financial restrictions to prompt new ideas in naval forces. [1]

Rising ship costs are forcing allied naval planners to seek alternative approaches to achieving and maintaining maritime security. Current ship building costs are outpacing inflation by 7-11%.[2] To put things in perspective, costs have risen for a guided missile destroyer by 123% between 1960 and 2005 (in 2005 dollars). In contrast, medical care and college tuition growth rates linger at 6.6% and 8.0% respectively. [3]

Naval strategists are currently at a crossroads. The transistor-information age revolutions have enticed planners to try and keep pace with emerging technologies to the detriment of spiralling cost. Unfortunately public funding has not matched the increased demand. The net result has caused a reduction in platforms rather than capabilities. Additional project costs have also resulted in increased public scrutiny and lengthen acquisition time. The unfortunate consequence to lengthy procurement is often obsolescence on arrival. These issues are not without precedent. The industrial revolution also saw an unaffordable rise in ship building cost coupled with significant advances in warship technology. For instance, the Royal Navy (RN)

---

[1] Ronald O'Rourke, "The Navy in a Time of Less Money," *United States Naval Institute Proceedings* 137, no. 11 (Nov 2011, 2011).
[2] Mark V. Arena, *Why has the Cost of Navy Ships Risen?: A Macroscopic Examination of the Trends in U.S. Naval Ship Costs Over the Past several Decades* (Santa Monica, CA: RAND, 2006), 15.
[3] Ibid., 2.

notes that the cost of a battleship rose from £1.8M in 1910 to £2.7M in 1912.[4] Comparatively speaking one battleship cost as much as 20 submarines. Back then, like today, finding the right fleet mix commensurate with the nation's strategic needs and available funding remains the greatest challenge.

SHRINKING FLEETS

Worldwide allied fleet sizes have decreased on average by 40% since the end of the Cold War.[5] Fleet sizes have shrunk primarily due to escalating acquisition *complexity* and *cost*. Figure 1 highlights the United State Navy's (USN) declining annual future shipbuilding projections in relation to declining budgets and overall fleet sizes. Note how every 5 years the USN anticipates reducing their build by one platform given a fixed acquisition budget. The trend is not unique to the USN but best depicted by them based on the sheer volume and consistency of their build programs.

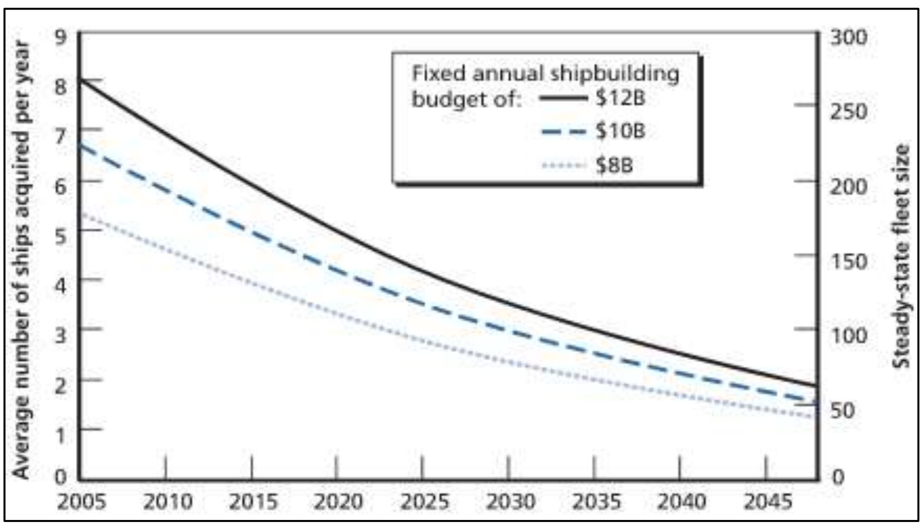


Figure 1 -USN Ships Acquired per year
Source: Arena, Why has the Cost of Navy Ships Risen, 3.

[4] Great Britain. Ministry of Defence, *Future 'Black Swan' Class Swoop-of-War: A Group System*, Vol. 1/12 (Shrivenham, Swindon: Joint Doctrine & Concepts Centre, 2012), 14.
[5] Bryan McGrath, *NATO at Sea: Trends in Allied Naval Power*, American Enterprise Institute,[2013]).

Rapid technological evolutions have necessitated frequent and laborious upgrades to platforms in order for them to remain capable and relevant. Most legacy platforms were not designed with mid-life modernizations in mind and therefore suffered from complex re-engineering in order to achieve their upgrade program requirements. Figure 2 illustrates the cost escalation by component of the USN's FFG-7 class during the transistor revolution of the 70s and 80s.

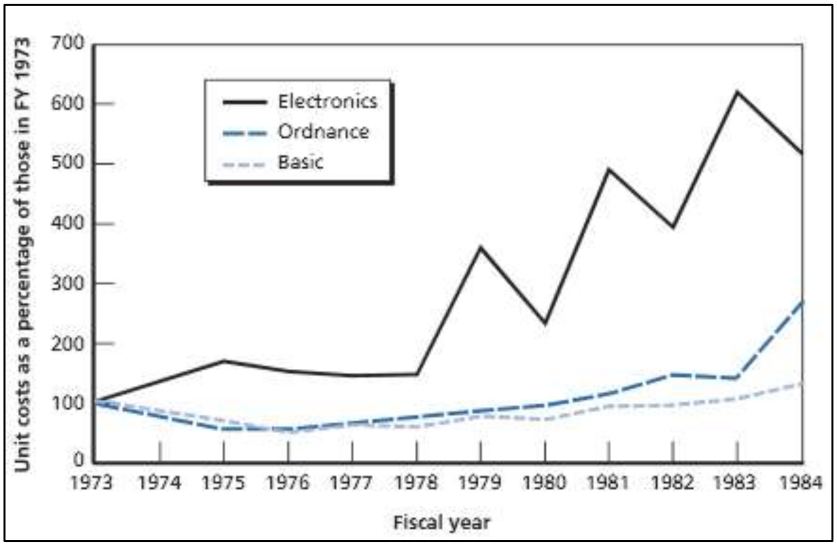


Figure 2- Component cost escalation for FFG-7 Class
Source: Arena, Why has the Cost of Navy Ships Risen?, 14.

The figure highlights how the increase in complexity associated with a technological revolution can significantly impact the cost of building a ship. Today amidst the information age revolution, cost are poised to dramatically escalate once again as the defence industry attempts to miniaturize and integrate these technological leaps into warship and ordinance design. The aforementioned ship *characteristic complexity* issues are not the only customer driven factors contributing to the annual shipbuilding inflation rate. RAND Corporation estimates that for major surface combatants, escalations in *standards, regulations and requirements complexity* add another 2.0% to the overall shipbuilding inflation whereas *characteristic complexity* adds 2.1% and the *procurement rate* adds 0.3%. In total these customer-driven factors only account for half of shipbuilding inflation. The other half rest largely on economic driven factors. These factors are categorized in three main areas: Labour, Equipment and Materiel. Independently labour and equipment loosely match consumer inflation at 2% each whereas materiel only 0.5%, but recall all these factors aggregate. In total all customers and economic factors amount to a 9% mean annual shipbuilding inflation rate. This rate is by no means static and at constant threat of escalation. The continued allied trend towards shrinking fleets will remain if shipbuilding inflation rates are left unmitigated. Fortunately there is a renewed awareness from our allies and a dramatic shift in their procurement strategies. The question remains, will these new strategies be compatible with the future maritime operating environment?

THESIS

Historically naval warfare has been centered on the tenants of attrition warfare; numbers count. Network centric warfare's (NCW) greatest champion Vice Admiral Cebrowski once said: "We need to adopt cost as a strategy". The Admiral was figuratively inferring to threating cost-saving measures equivalent to any other strategic *Course Of Action* (COA). [6] This paper will take that notion one step further by stating that *distribution* is the key to adopting cost-savings as a strategic COA. Distribution does not simply refer to spreading cost around but rather distributing all aspects within the Naval Enterprise. As such, cost-saving strategies can be generated by *distributing forces*, *distributing effects*, *distributing sustainment* and *distributing acquisition*.

[6] Admiral Cebrowski considered by many as the father of naval NCW held key appointments as President of the Naval War College and Director of the Office of Force Transformation. In this capacity he championed DoD wide initiatives that would enable America's competitive military edge under fiscal constraints.

OUTLINE

The overall intent of this research paper is to conduct a Royal Canadian Navy (RCN) feasibility study into allied cost-saving strategies. The analysis will examine common allied trends in cost-saving measures, mitigating strategies and evolved operational structures that compensate for the decline in platforms. Each cost-saving strategy will then be applied to the RCN context given Canada's unique particularities. Once applied to the Canadian context, a COA development study will be conducted which involves grouping, phasing and sequencing applicable RCN cost-saving strategies. An impact analysis will then be performed in order to compare and contrast the RCN's current fleet against a proposed *Virtual Fleet* generated from RCN applicable cost-savings strategies. Fleet structures, task group composition, platform requirements and operational practices will be areas of particular interest. Future naval doctrine will remain an underlying theme throughout the paper. The Canadian feasibility of a number of these cost-saving strategies will require looking into historical precedents as well as the current and future geo-political climate. These strategies are not transformational on their own but their aggregates have the potential of shaping a unique and capable future fighting force.

METHODOLOGY

The genesis for our allies to conceive new and innovative cost-saving strategies is primarily aimed at mitigating the impact of shrinking fleets. "In order to remain effective – and to counter potential asymmetric threats- *distributed operations* must be the centerpiece of any future concept of operations". [7] As previously stated, distribution is the underlying theme of most allied cost-savings strategies. For ease of analysis these cost-saving strategies are grouped into

---

[7] Daniel Goure, "Modularity, the Littoral Combat Ship and the Future of the United States Navy," *Lexington Institute* (2006).

four major categories: *distributed force, distributed effect, distributed sustainment* and *distributed acquisition*. The following chapters will analyse allied cost-savings strategies by introducing the related concepts, identifying participating nations, comparing trade-offs (capability and capacity) to potential return on investments (ROI) and finally applying a validity analysis to determine their feasibility for the RCN.

Each cost-savings strategy's validity will be scored and analysed through the lens of the COA validity characteristics outlined in the Joint Operations Planning Group (JOPG) but modified in order to suit the analysis. [8] The JOPG was chosen as it is the same process utilized by Chief of Force Development's (CFD) capability based planning process from which all present and future Canadian Forces acquisition programmes are derived from. [9] Appendix A outlines the scoring matrix parameters:

1. *Completeness* will speak to the strategy's maturity. For example, a strategy advocating the use of all-electric ships vice conventional prime movers in order to save on fuel cost would score a 9/9 since according to Appendix A this strategy has been proven operationally with the Type-45 Royal Navy Destroyer;
2. *Suitability* verifies if the strategy actually saves money in the Canadian context and could develop into a ROI. All-electric ships offer several cost-reduction attributes. For instance the concept permits prime movers to me placed closer to the shaftline freeing up weight and space for additional fuel. The Type-45 has a range of 7000nm at 18knots largely attributed to its propulsion configuration. In contrast, the USN's Arleigh Burke

[8] Canadian Forces College and College des Forces Canadiennes, *CFC Guide to CF Operational Planning Process* (Toronto, ON: Canadian Forces College, 2008).
[9] Canada. Department of National Defence, Chief of Force Development, *Capability-Based Planning Handbook*, 2014).

conventionally powered destroyer has a range of 4400nm at 20knots. This concept is advantageous in the Canadian context since it could feasibly reduce the amount of oilers required to sustain the fleet. At first glance this strategy yields a 37% increase in fuel efficiency and according to Appendix A scores 9/9 since its ROI exceeds 30%[10];

3. *Acceptable* evaluates acceptable risk profiles drawn from two extensive fleet mix studies conducted by DRDC CORA. [11] The methodology used in the study incorporates employment scenarios, platform capabilities as well as scale of political impact in order to derive a risk threshold that determines which fleet mix would best suit Canada's needs. Appendix B illustrates the scoring matrix utilized by CORA to determine navy objectives. The threshold determined for each cost savings strategy is compared against the risk threshold of the current fleet outlined in Figure 3. The working assumption is that the current fleet is acceptable as a baseline.

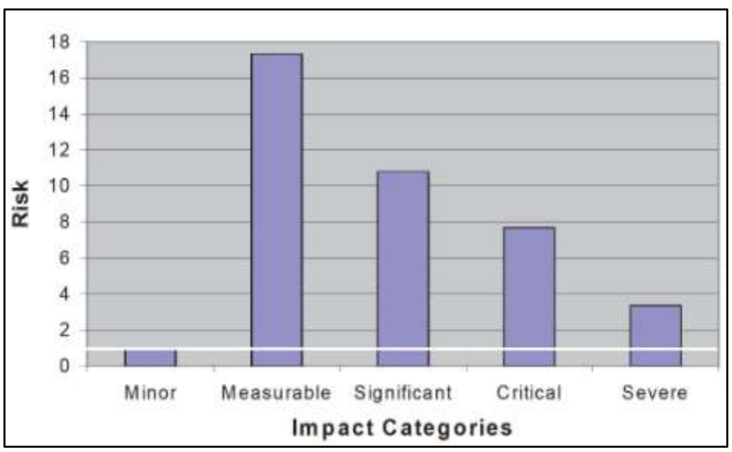


Figure 3-Current Fleet Risk Profile
Source: Allen, Fleet Mix Study,30.

[10] No analysis was conducted; this example is provided for illustrative purposes only.
[11] D. Allen and D. Blakeney, *Fleet Mix Study: Determining the Required Capacity and Capability of the Future Surface Naval Force Structure* , Vol. 2005-38 (Ottawa: Centre for Operational Research and Analysis, Defence R&D Canada, 2005).

The analysis of *Acceptability* for most cost-saving strategies will be compared against the current fleet, CFDS proposed fleet, and 3 cost equivalent fleet-mixes. The all-electric fleet concept would again score 7/9 given the 37% fuel efficiency bonus afforded by an electric propulsion because in accordance CORA's Fleet Mix II the addition of one oil tanker would reduce aggregate fleet risk by 60% compared to the current fleet[12];

4. *Feasibility* will evaluate the naval enterprise's capability and capacity to conduct the cost-saving strategy (industry, Department of National Defence, RCN) in terms of resources (people and money). Industry has the capacity and capability to produce an all-electric fleet for the RCN. The RCN operates 4 diesel electric submarines and could be considered to have the capability but not capacity of scale. DND did procure the Upholder class in an adhoc manner but has yet to fully program manage an electric propulsion infrastructure of any scale. The strategy would subsequently score a 7/9 in accordance with Appendix A; and
5. *Exclusivity* evaluates to what degree the RCN is already pursuing the strategy and how operationally sound the strategy is in doctrine. All-electric surface ships has been discussed in various unreleased strategic documents for some time but has yet to be enshrined in doctrine or appear in statements of requirements for future builds. The strategy would score an 8/9 according to Appendix A.

The combined tally of each validity parameter provides its respective cost-saving strategy with a unique percentage score. This score permits the cost-saving strategy to be compared and categorized against other allied cost-saving strategies. Cost-saving strategies scoring below 70%

---

[12] For illustrative purposes 37% fleet fuel efficiency increase is equivalent to one virtual AOR Alex Bourque and Cheryl Eisler, *Fleet Mix Study Iteration II: Making the Case for the Capacity of the "Navy After Next"*, Vol. 2010-159 (Ottawa: Centre for Operational Research and Analysis, Defence R&D Canada, 2010).

will be categorized as *Routine Strategy* whereas between 70%-80% as *Essential Strategy* and above 80% as *Critical Strategy*. Routine Strategies do not necessarily need to be adopted by the RCN as they likely do not meet the aggregate validity threshold. Both Essential and Critical Strategies should be adopted by the RCN but defer in their urgency. In the case of the all-electric fleet, the strategy has a combined score of 40/45 or 88% categorizing it as a *Critical Strategy* for the RCN.

In order to appreciate how allied cost-saving strategies could be applied to the Canadian context, a basic understanding of Canadian geo-political factors that influence government policy making and by extension RCN procurement, operations and force structure will be conducted. The following *Politic, Military, Economic, Social, Information and Infrastructure* (PMESII) analysis provides an appreciation for Canadian applicability of allied cost saving strategies.

PMESII

The intent of this section is not to do an exhaustive analysis of Canada's geo-political context but rather highlight the factors germane to the subsequent RCN validity analysis. Figure 4 summarizes Canada's National Interest in terms of intensity.

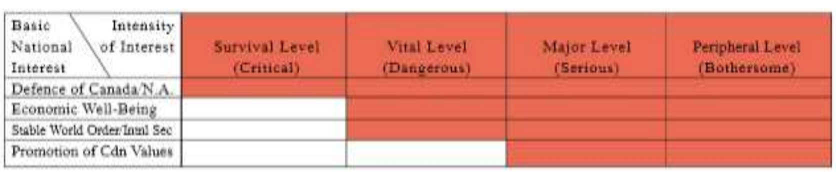


Figure 4- National Interest Matrix Differentiation of Canada's Interest
Source: Finan,Illustrative Canadian Strategic Risk Assessment,30.

Appendix C summarizes Canada's geo-political threats based on Figure 4's national interest matrix. The Appendix aids in understanding the *acceptability* of potential Canadian cost-savings strategies.

Political

Canada is a member of the Artic Council and continues to exert influence on the forum in order to shape future international agreements. Artic sovereignty is a current government mandate. [13] The government is an active and willing participant in humanitarian assistance, war on terrorism and overall international security. [14] The government wishes to have a voice in international affairs and acknowledges that they must be prepared to act if they wish to have a place at the table. [15] This government requires a navy that is flexible, multi-role with a moderate surge capacity. The government's Artic ambitions means they need to show some measure of presence and situational awareness up north. Dedicating one class strictly for the Artic is an expensive proposition given the aforementioned other political objectives and therefore acquiring classes of ships that provide "good enough" solutions is a common theme in Naval procurement.

Military

Canada's domestic military posture is largely shaped by its proximity to the US and the relative isolation provided by three oceans. Canada holds a unique defence relationship with the US based on shared mutual interest in the defence of North America. The unique relationship also extends to access of American defence capabilities and technologies. Canadian procurement can shy away from the American defence industrial base but not too far from it. Memorandums of Understandings (MOUs), frequent interoperability, weapons consortiums and shared development means that Canadian defence planners must consider the impact on Canadian-American relations during procurement.

---

[13] Franklyn Griffiths, P. W. Lackenbauer and Robert N. Huebert, *Canada and the Changing Arctic : Sovereignty, Security, and Stewardship* (Waterloo, Ont: Wilfrid Laurier University Press, 2011).

[14] Aaida Mamuji, "Canadian Military Involvement in Humanitarian Assistance: Progress and Prudence in Natural Disaster Response," *Canadian Foreign Policy (CFP)* 18, no. 2 (06, 2012), 208-224.

[15] Cristina G. Badescu, "Canada's Continuing Engagement with the United Nations Peace Operations," *Canadian Foreign Policy* 16, no. 2 (Spring 2010, 2010), 45-IV.

Economic

Two key federal government policy documents emphasise Canada's reliance on maritime trade. The *Global Action Plan* and *Seizing Global Advantage* highlight the need for economic diplomacy as well as singles out countries that show beneficial trade potential arrangements with Canada. [16] These chosen countries are reliant on maritime trade with Canada in order to fulfill those arrangements. Secure access to the maritime commons is paramount for Canada's economic prosperity.

Social

Naval presence in Canada is removed from most major urban centers. Canada also has a vibrant and growing multicultural society. Toronto, Vancouver and Montreal have 49.7%, 39.6% and 20.6% of their population foreign born. Figure 5 illustrates the distribution of foreign born nationals in Canada and US. The figure highlights the potential social pressure that could be exerted on the government if security events occur in their countries of origin.

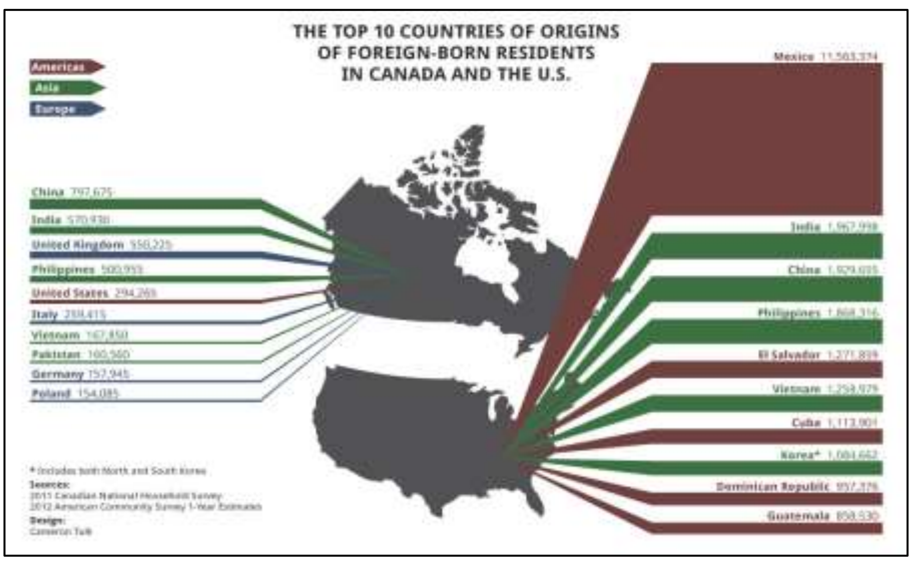


Figure 5- Foreign-Born Residents in Canada and the U.S
Source: 2011 Canadian National Household Survey,2012 American Community Survey 1 year Estimates

---

[16] Marketwired, "Harper Government Launches New International Trade Plan," *Marketwire* (11/27, 2013).

That said, social opinion with respect to the military remained relatively unchanged from 2010 to 2014. Appendix D illustrate the results of an Ipsos public opinion poll ranking CAF military mission priorities. The poll suggests that Canadians wish the CAF to perform the following:

1. Disaster relief in Canadian communities;
2. Search and rescue services for Canadians;
3. Patrolling our land, maritime, air space;
4. Protecting our ocean trade routes;
5. Canada's sovereignty in our North; and
6. Fighting war on terrorism.

Information/Infrastructure

The World Economic Forum indicates that Canada has a well-developed *information* and *infrastructure*. Canada’s Global Competiveness Index (GDI) ranking is 14th of 148 countries.[17] GDI evaluates several pillars to derive the GDI, namely education & training, innovation and infrastructure. Canada ranks 16th, 21th and 12th respectively worldwide which highlights the country’s strengths. On paper this means Canada has the capacity and capability to create and sustain industries such as naval shipbuilding. This also means that Canada has the agility to manage and aggregate information which is of particular interest where information dominance at the strategic, operational and tactical level has significant correlations with cost-savings.

[17] Klaus Schwab, "The Global Competitiveness Report 2014-2015," *World Economic Forum* (2014). http://www.weforum.org/reports/global-competitiveness-report-2014-2015.

OPERATING ENVIORNMENT

Physical: Sea/Air/Land

Canada is bordered by 3 oceans. Appendix E illustrates Canada's domestic operating environment, namely ice patterns and potential trade routes. The Appendix also outlines future staging and Artic shipping routes that must be considered when evaluating potential cost-saving strategies.

Space vs Time vs Force

The RCN's last major strategic policy documents include *Leadmark 2020* and *Charting the Course from Leadmark* published in 2001 and 2005 respectively. The strategic ambitions highlighted in these documents have remained relatively unchanged but their executions have been course-corrected by the Canadian First Defence Strategy (CFDS) which highlights the acquisition of six to eight Artic Offshore Patrol Ships (AOPS), three Joint-Support Ships (JSS), fifteen Canadian Surface Combatants (CSC), and the modernization of twelve CPFs. Appendix F summarizes current and future RCN major capital projects. Present day disposition of RCN projects are as follow: The Halifax Class modernization (HCM) is slightly delayed but well underway; AOPS project will likely commence cutting steel late 2015 yet has requested additional funding in order to meet the minimum six platform requirement outlined in CFDS; JSS has adopted a Military-Off-The-Shelf (MOTS) design based on the Berlin Class Auxiliary Oiler Replenishment (AOR) ship; and CSC which has been a program of record in one form or another since 1999 has yet to announce its procurement strategy. The RCN has no programs of record for a Victoria Class submarine replacement or a future Unmanned Vehicle capability (UV). The aforementioned new builds fall under the hospice of the National Shipbuilding

Procurement Strategy (NSPS), a strategy aimed a reinvigorating Canadian Fleets, industry and institutions. [18]

The current narrative for these capital projects highlights the fact that the RCN is facing the same dilemma as their allied partners. Firstly, technological evolution such as midlife refits are complex and rife with delays. Secondly, additional funding or MOTs designs are a means of mitigating increased shipbuilding cost. Lastly, long-standing programmatic delays cause projects to introduce obsolescence on delivery.

Allied trends in cost-savings may or may not be applicable to RCN's strategic realities. Some may be applicable in intent but immature while others may be feasible but too resource intensive. The cost saving strategies in the following chapters have been adopted by allies because they have recognised the potential of mitigating their shrinking fleets. The question remains, based on the Canadian geo-strategic context, scale and ambitions, which strategies should the RCN adopt? The overall aim of this paper is to identify those cost-savings strategies that are relevant to the Canadian context.

> *All of the sophisticated talk about grand strategy is helpful, but show me your budgets and I will tell you what your strategy is.*
>
> -General Colin Powell[19]

[18] Jean Grace, "A Team Sport: Canada Continues its Surface Fleet Renewal," *Jane's Navy International* 120, no. 4 (May 1, 2015, 2015c).
[19] Colin Powell, "The Changing Foreign Policy Environment", lecture to the Woodrow Wilson School at Princeton University, February 13, 1989.

CHAPTER 1: DISTRIBUTED FORCE

The USN surface community suggest that globalization and the information age are providing the catalyst for a transition from the carrier era to a networked battle fleet era. This transition is akin to the transition that air power facilitated from the battleship to the carrier era. [20] Robert O. Work proposes that a large concentration of naval power such as a carrier strike group is still applicable in peer-to-peer confrontations but highly unlikely given globalization and largely inadequate against asymmetric adversaries. [21] Secondly, concentration of fire power also comes with concentration of risk and the cost associated with mitigating that risk.

> Over the course of history the central problem of naval tactics has been to attack effectively, that is to say, to *bring the firepower of the whole force into battle simultaneously*. A second and subordinate objective of naval tactics has been to try to concentrate one's whole force on a portion of the enemy's in order to defeat him in detail. [22]

Purpose built high value platform must be protected by an array of expensive multi-role platforms. The overall impact is that a significant portion of one's sea power assets are spatially limited to the location of one's main effort.

Today's asymmetry unfortunately removes the simplicity of having a main effort to concentrate your forces and introduces multiple fronts dispersed over time and space. The maneuverist approach suggests countering dispersed fronts by distributing forces. [23] As the name implies, distributed forces insinuates dispersing your assets internationally, regionally and

---

[20] Three key WWII engagements cemented the carrier's position as the preeminent capital ship: Firstly on November 11th 1940 a British carrier engaged and defeated 3 Italian battleships anchored in Taranto. Secondly December 10th 1940 Japanese torpedo bombers sank British battleships Prince of Wales and Repulse. Thirdly, the attack on Pearl Harbor sparred the carrier fleet to the detriment of the battleship fleet.

[21] Robert O. Work, *Naval Transformation and the Littoral Combat Ship* (Washington, DC: Center for Strategic and Budgetary Assessments, 2004), 12.

[22] Wayne P. Hughes, *Fleet Tactics and Coastal Combat*, 2nd ed. (Annapolis, Md.: Naval Institute Press, 2000), 43.

[23] William S. Lind, *Maneuver Warfare Handbook* (Boulder, Colo.: Westview Press, 1985), 4.

locally. Within the context of cost saving strategies, being everywhere at the *same* time, with cost-equivalent capabilities alludes to a larger more expensive force. That said, cost can be lowered if risk is increased. Risk can be increased if it is distributed and managed accordingly. *Quantity as a quality*, *high-low mix, squadron teamwork* and *evolved interoperability* are all strategies and concepts that are intended to manage risk, and ultimately reduce cost.

QUANTITY AS A QUALITY

The USN's operational tempo has significantly increased since the end of the Cold War yet their fleet size has been reduced by 40%. The USN responded on average to 2.9 crises per year between 1970 to 1989 with an average crisis length of one month. Between 1990 and 1996 the USN responded to 5.0 crises per year with an average duration length of one year. [24] Crisis response usually comes from the USN's surge capacity and not from their force generation and deterrence obligations. The USN maintains six of eleven Carrier Strike Groups (CSG) ready to deploy within 30 days while two more are ready to deploy within 90 days. Although CSGs do not contribute to all crisis responses, they do represent the USN's primary conventional deterrent efforts. The USN has since recognised the importance of the strategic deterrent effect of being present. Presence is deemed to be a mandate yet is difficult to be achieved given their current fleet structure.

Allied navies alike are starting to appreciate and plan for quantity as a quality. The RN envisions introducing a light future concept ship duly named *Black Swan Class 'Sloop-of-War'* in significant quantities. [25] The class is intended to be inexpensive and mass produced. The future concept aims to assure a persistent and responsive presence to the global commons while

[24] C. B. Barfoot, "Crisis Response:Analysis of Historical Data," *Center for Naval Analysis* (1997).
[25] Great Britain. Ministry of Defence, *Future 'Black Swan' Class Swoop-of-War: A Group System*, 14.

ensuring access in the littoral. The concept is not new; Admiral Cerbrowski introduced the streetfighter concept to the USN that ultimately gave birth to the Littoral Combat Ship (LCS).[26] The original streetfighter concept intended to introduce a class that was inexpensive and agile which would capitalize on superior numbers and interconnectivity in order to compensate for its inferior survivability and firepower. Today the USN remains committed to the LCS representing 25% of the surface fleet however the original design will be up-gunned and up armoured in order to increased survivability. The redesign shies away from the original conceptual framework but stays true to the original intent; numbers count. [27]

The French and German navies are soon to introduce similar concepts. *La Marine National* is set to build a suite of long endurance light 1500t Offshore Patrol Vessel (OPV) named *Batiment Multimission* aimed primarily at constabulary functions for 100M€. *La Marine National* also has planned ten highly capable Gowind class Corvettes at a cost of 350M€. The *Deutsche Marine* is looking to capitalize from the MEKO family's scalability in order to increase their overall numbers.

Despite the perceived trend of shrinking fleets, the aforementioned examples are indications that navies are *planning* on increasing fleet sizes. These increases do come at the expense of capabilities and follow on sections will examine some strategies that mitigate the loss or reduction of those capabilities. However, it is clear that individual platform sophistication would need to be scaled down in order to afford mass quantities. In doing so the trade-off

---

[26] Work, *Naval Transformation and the Littoral Combat Ship*, 48.

[27] The original framework anticipated inexpensive seaframes that could be mass produced. Controversies over cost growth as well as design and construction issues have forced DoD to reavaluate the program. The last 20 hulls will be designated as Frigates and maintain up to 80% commonality with Flight 0 Littoral Combat Ships. See Ronald O'Rourke, *Navy Littoral Combat Ship (LCS) Program: Background and Issues for Congress* (Washington, D.C.: Congressional Research Service, Library of Congress, 2014b) ,1.

becomes an increased capability sophistication vs the influence afforded by a larger size '*Fleet-in-Being*'.[28]

The strategic deterrent effect of a robust and prominent *Fleet-in-Being* cannot be understated. The cost-saving potential of a sizeable fleet are not operational but rather strategic in nature. The very concept of *Fleet-in-Being* is an insurance policy against the disruption to global trade.[29] The return on investment is indeed the assured continuation of our way of life and standard of living. Consider the lost revenue associated with piracy originating from one failed state. Now reconsider the same situation in a world with an increased population and fewer points of origins for resources. Trade will increase and so will the need to protect it. The question remains, how low can capabilities be reduced in order to afford a significantly desirable *Fleet-in-Being*?

CORA's Fleet Mix Study II directly addresses the issue of fleet size with respect to associated risk in accordance with Appendix B metrics. Table 1 illustrates three iterations of optimal fleet composition necessary to reduce risk to an insignificant level.[30] These iterations are the minimum number of platforms required to justify quantity as a quality. The report outlines the methodology utilized to derive each iteration but in essence roughly 30 CSCs are required to satisfy Canada's maritime security objectives within an acceptable risk threshold. The following analysis examines the applicability of quantity as quality for the RCN:

---

[28] John B. Hattendorf, "The Idea of a "Fleet in being" in Historical Perspective," *Naval War College Review* (2014), 3.

[29] Ibid., 14.

[30] An illustrate example being a metropolitan police force in sufficient numbers to reduce crime to an insignificant number. This assumes that sufficient numbers prevents crime as well as swiftly deals with escalating situations.

Table 1 Optimal fleet obtained through minimizing risk category

Fleet Mix Options																			
Number of ships	Starting Fleet	MH		AOPS		MCDV		SSK		JSS		LMS		CSC				
														C2AD		MP		CSC Sub-
		East	West	East	West	East	West	East	West	East	West	East	West	East	West	East	West	
75	Zero	7	7	5	3	10	10	6	5	2	1	2	1	4	3	12	11	30
71	CFDS	7	6	3	1	11	11	5	5	2	2	2	1	4	3	11	10	28
76	Target	7	7	4	2	10	10	6	5	2	1	2	2	4	3	13	12	32

Source: Bourque, Eisler, "CORA Fleet Mix Study Iteration II", 50.

1. Completeness: [8] Low-end mass produced platforms are quite mature however blue water independent lower-end platforms such as the LCS are quite new to market;
2. Suitability: [1] The study calls for about 30 CSC platforms which is completely unaffordable given Canadian government's defence budget[31];
3. Acceptability: [9] The proposed fleet mix was purposefully designed to minimize risk;
4. Feasibility: [4] Canadian industry does not have the capacity to produce such a large fleet. The RCN does not have the personnel or infrastructure to operate it. DND does not have the resources to procure or manage such an undertaking; and
5. Uniqueness: [8] The concept was successfully employed in the RCN during the battle of the Atlantic. That said, today the platforms proposed by our allies are quite novel and currently reside as strategic concepts for the RCN.

The strategy scores quite low in the validity analysis [66%] and supports the fact that this approach remains at the conceptual level with most allies. This strategy should be considered a *Routine Strategy* for the RCN. Distributing forces as a cost saving category is not solely limited to platform numbers but also requires a look at fleet composition. The following section investigates if indeed modifying fleet mix is a more appropriate cost-saving strategy for the RCN.

[31] Assuming $2B per CSC would cost $60B which far exceeds the proposed $26.2B outlined in Appendix F.

HIGH-LOW MIX

Whereas maritime roles such as *Maritime Security* and *International Engagement* benefit from a large low-end fleet, warfighting does not. Despite the appeal of increasing fleet sizes at the expense of platform capabilities, warfighting remains a likely scenario and cannot be discounted. As such there remains a need to maintain a balanced fleet mix. The cost-saving strategy here is all about optimizing a fleet's high-low mix. Intuitively cost-saving occurs when high-end platforms are minimized and low-end platforms increased however factors associated with high end platforms that contribute to increased deterrence such as reach, endurance, striking depth and concentration of force cannot be underestimated. The mere fact of possessing these factors may deter and avert costly confrontations that otherwise would occur with a war of attrition involving the low-end platforms. Adversaries may otherwise be enticed to escalate a conflict if they know a large low-end fleet cannot affect their Center of Gravity (CoG) or main effort. Conversely, low-end platforms are often smaller and have the ability to thrive in the littoral where larger higher-end platforms cannot. A high-end centric strategy without a legitimate requirement increases risk to public acceptance and thus programme approval. A low-end centric strategy increases risk to security and thus public safety. The fact remains that an optimal balance needs to be achieved in order to maximize cost-effectiveness.

Western navies continue to struggle in finding the right mix despite the end of the Cold War. Appendix G illustrate fleet mixes of the UK, France, Italy, Germany, and Spain from 1995-2013. Appendix G does not depict future planned builds but highlights current trends in allied fleet mixes. The RN remains firmly committed to its submarine force in spite of sharp reductions in their carrier and destroyer force. The RN is currently building only one carrier and has approved the acquisition of 12-13 Type 26 frigates at a cost of £400M per ship which further highlights its trend towards cheaper and smaller surface platforms. In addition, the RN has recently commenced building three River Class OPVs. These vessels are set for delivery in 2017 at a cost of £116M per ship.

The French Navy has sharply decreased its lower-end frigates in proportion to other higher-end platforms. These figures do not represent the remaining FREMM class frigates builds as well as the aforementioned *Batiment Multi-Mission* and *Gowind* classes which if they are all built would tip the scales towards a much lighter fleet mix. In fairness the *Gowind* class is intended to be highly capable as it leverages modern technology's density and scalability. The German Navy is steadily increasing its frigate force with the introduction of the F125. Fleet composition has remained relatively stable however the scalability of the MEKO family of ships has offered the German Navy the ability to quickly transition to low-end as required. "The Germany Navy—unlike the Royal and French Navies—does not have a desire to be a balanced force capable of significant power projection, amphibious operations, and strategic deterrence. As its aims have been historically more modest, they have been more capable of being supported" [32]. The Bundeswehr indicated in both their 2011 Defence Policy Guidance and 2006 White Book that the greatest threats to German security are terrorism, failed states, organized crime and restricted access to resources. As such the navy is slowly repositioning itself from a Blue Water escort Navy towards an expeditionary navy. [33]

Spain and Italy are trending opposite to the other allied nations. Both of their frigate forces have significantly been reduced despite marginal gains in their higher end destroyer force.

[32] McGrath, *NATO at Sea: Trends in Allied Naval Power*

[33] Expeditionary navy suggest emphasis on maritime mission such as counter-piracy, disaster relief and littoral combat as opposed to traditional blue water missions such as carrier escort and ASW. See Albrecht Muller, "New Frigate Underscores Germany's Shift from Cold War Naval Combat," *Defense News*, Jan 13 2014, 13.

Spain and Italy have fallen victim to imposing fiscal realities that have forced naval planners to re-evaluate their strategies and ambitions. [34] Their current trend tends towards a more balanced fleet mix but this remains to be seen.

The 2013 Australian Defence White Paper calls for the acquisition of a balanced fleet mix of new submarines, future frigates and OPVs. In doing so, the Royal Australian Navy (RAN) has recently announced the Pacific Patrol Boat project which aims to acquire 20 purpose built OPVs in partnership with 13 Pacific island nations. Following the government's 2013 election the RAN has been musing over the acquisition of the Austral variant of LCS. That said the ongoing acquisition of their Air Warfare Destroyer and Landing Helicopter Dock (LHD) suggests that the RAN continues to have a balanced fleet ambition. This is similar to the USN's balanced fleet ambition despite their desired 25% LCS fleet composition. Appendix H illustrates a fleet composition comparison from three significant DoD reviews. Put into context, LCS aims at replacing 3 classes into one therefore conceptually the USN's ambitions remain balanced.[35]

An improperly balanced fleet represents lost opportunity cost for alternative platforms. France and Britain continue to maintain strategic ballistic nuclear deterrents and carriers whereas as Australia and Germany do not nor have they ever strived to do so. All allied navies still strive for a balanced fleet at the cost of reduced fleet sizes. Universally these navies suggest that in today's context, breath is more important than depth and that holding on to certain capabilities assures flexibility for an uncertain future. The following will investigate if a balanced fleet strategy is applicable for the RCN:

---

[34] Italy seeks to slowly reinvigorate their fleet with a recently announced strategy however their fiscal realities have not changed. Luca Peruzzi, "Italian Navy Anticipates Key Contracts in Fleet Renewal Process," *Jane's Navy International* 120, no. 4 (May 1, 2015, 2015).
[35] Envisioned LCS operations may engender a new naval construct, see: "Opinion - LCS: The US Navy's 'Disruptive' Warship." *Jane's Defence Weekly* 50, no. 12 (Feb 20, 2013, 2013b).

1. Completeness: [9] The RCN currently employs a balanced fleet mix;
2. Suitability: [1] The concept would be cost equivalent and no direct savings would be attributed. Balance infers maximizing platforms within a current budget envelop;
3. Acceptability: [7] CORA Fleet Mix Study II directly addresses this issues. Table 2 illustrates the composition of the three main cost equivalent fleets used in their analysis.

Table 2 Cost equivalent fleet composition compared the Target and CFDS fleet

Fleet Mix Options																	
Option	MH		AOPS		MCDV		SSK		JSS		LMS		CSC				
													C2AD		MP		CSC Sub-Total
	East	West	East	West	East	West	East	West	East	West	East	West	East	West	East	West	
Option 1	8	7	4	2	6	6	2	2	1	1	0	0	2-	1-	7-	5-	15
Option 2	8	7	4	2	6	6	2	2	1	1	0	0	0	0	5	5	10
Option 3	8	7	4	2	6	6	2	2	1	1	0	0	0	0	8- -	7- -	15

Source: Bourque, Eisler, "CORA Fleet Mix Study Iteration II", 41.

All fleet compositions with the exception of Option 3 significantly reduce risk. Figure 13 displays the output of their analysis. Option 3 highlights the fact that going too low-end holds significant risk above the RCN's current risk level;

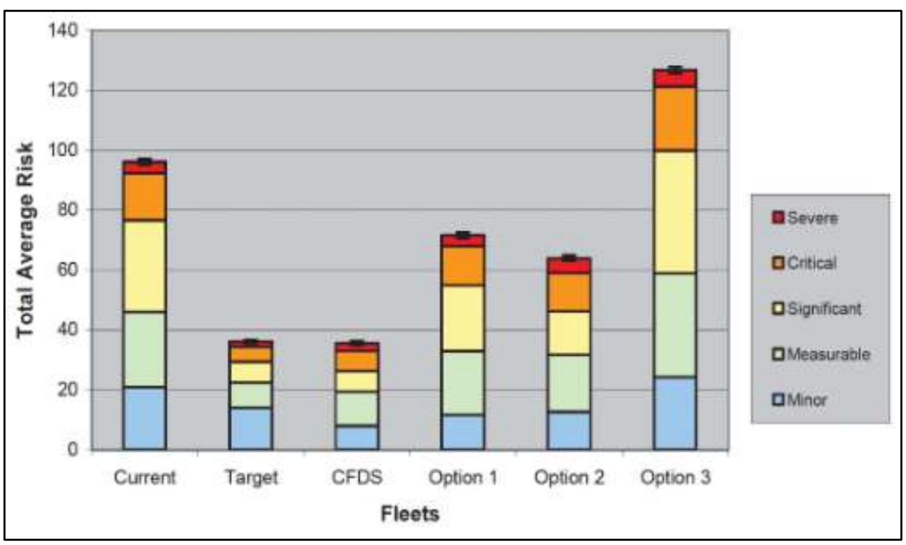


Figure 6 Comparing total Risk of SME preferred to cost equivalent fleet options
Source: Bourque, Eisler, "CORA Fleet Mix Study Iteration II", 42.

4. Feasibility: [8] NSPS is gaining momentum. The strategy is building capacity and capability in the industry, RCN and DND; and
5. Uniqueness: [1] The concept is not new; the RCN has analysed and implemented its fleet composition on several occasions.

The strategy scores quite low in the validity analysis [58%]. Fleet Mix studies are standard business and should be continuously updated and implemented. This strategy should be considered a *Routine Strategy* for the RCN and a pre-condition to any COA.

SQUADRON CAPABILITY SHARING

The notion of capability sharing is not new, it is firmly ingrained in the task group concept. Task groups employ various distinct classes of ships that contribute different capabilities. This mosaic of classes provides task group commanders a full spectrum of warfighting abilities in order to accomplish a task. Traditional task groups by virtue of their composition are an expensive solution to a problem. For instance, task groups are often centered on protecting a high value force multiplying asset with platforms that specialize in a given warfighting domain. An even more expensive solution is protecting a high value asset with several similar multi-role platforms. Classes of ships, by definition are a grouping of correspondingly purposed platforms. A squadron on the other hand is a grouping of similar platforms that work together in order to accomplish a task. Consider a squadron as a homogenous task group.

The concept of squadron capability sharing fuses all three aforementioned task group concepts in one cost-effective manner. For example, consider a squadron of low-end platforms. The task group, by virtue of low unit cost can afford to have greater numbers. First, the force multiplying effect is satisfied by their large quantities and reduces the need to bring and protect a high value asset dedicated to a task. The concept resembles *Joint Fires* which will be discussed in the *Distributed Effect* chapter. A squadron of surface ships providing direct or indirect fire support, given today's long range gun based precision projectiles, is far more cost effective then a Carrier Strike Group. Additionally, Air Superiority is not required in order to achieve the same effect. This of course would be mission dependant but illustrates the force multiplying effect of aggregating simple capabilities. [36]

Second, squadron capability sharing also satisfies a Task Group's ability to conduct full spectrum warfare in a cost effective manner. A squadron of numerous low-end platforms can configures each individual platform in the same manner as a fighter squadron would with different payloads rather than employ different classes of ships to fulfill warfare area obligations. Reconfiguration is made possible through modularity covered in the *Distributed Effects* chapter. Cost-saving occurs through commonality in training, acquisition and sustainment as well as scalability of squadron size. These concepts are covered in the *Distributed Sustainment and Acquisition* chapters. Lastly, the usage of multi-role platforms becomes redundant as their role diversity becomes distributed amongst the squadron through modularity. Sensing and striking reach of a singular high-end multi-role platform becomes satisfied by the squadron through net-centric warfare concepts covered in *Distributed Effects*.

Thus far only the USN has fully embraced employing the squadron capability sharing concept. A 2004 Center for Strategic and Budgetary Assessments (CSBA) report on the LCS suggest variations of squadron capability sharing concept. [37] Variations include large pools of

[36] Similarly a squadron of three low-end platforms in a patrol box can divide the area in two parts freeing the third to resupply in port. This scenario reduces the need for an AOR and requirement to protect it with dedicated assets.
[37] "CSBA Report Identifies Questions regarding Modularity for LCS." *Defense Daily* 221, no. 32 (Feb 20, 2004, 2004), 1.

baseline LCSs stationed at homeport only reconfigured in theatre or squadrons pre-configured with mixed mission packages. The common theme in the report is to configure and group squadrons as if they were acting as a unitary multi-mission ship. The report also suggests that grouping large squadrons of singular capability variants faired extremely well during war gaming. The RN's Black *Swan Class 'Sloop-of-War'* Joint Concept Note envisions numerous squadrons that share capabilities. The concept note suggests a squadron of four Black Swans should cost the same as one multi-role platform in order for the concept to be effective. [38]

In essence the very notion of distributing capabilities amongst a squadron of low-end platforms inherently insinuates a capability trade off. Capabilities are shared and there is a premium associated with coordinating effects and reconfigurations. Resources are shared and teamwork is a requirement. The ROI lies within the cost savings and the ability to reinvest those savings in additional platforms or future mission modules. Forces multiplication through concentration of forces such as joint fires reduces the need for specialized high value platforms. The concept is at its infancy and therefore very few actual metrics are available to determine the levels of savings squadron capability sharing could generate. Despite the strategy's state of maturity, squadron capability sharing may be applicable to the RCN given the fact that Canada has traditionally acquired classes of ships in proportionally large amounts. [39] The following analysis will determine if indeed squadron capability sharing is a valid cost-saving strategy for the RCN:

1. Completeness: [6] The RCN currently employs the task group concept and could transition to a homogenous task group concept. As a matter of fact, the command variant

---

[38] Great Britain. Ministry of Defence, *Future 'Black Swan' Class Swoop-of-War: A Group System*, 21.
[39] Relative to the overall size of the RCN fleet

of the modernized Canadian Patrol Frigate may indeed be the catalyst. The LCS is intended to operate in this manner but has yet to exercise the strategy as platforms have not been introduced in sufficient numbers;

2. Suitability: [9] The strategy is predicated on employing *Distributed Effect* strategies. The *Plug & Fight* and *Unmmaned Vehicle* sections further analyze the RCN's suitability. *Royal Danish Navy* (RDN) and USN studies suggest ROI of 38%[40];
3. Acceptability: [5] The concept is based on sharing risk. Risk does not increase; it is simply distributed amongst platforms. Looking at this strategy in isolations, risk should remain the same as the current fleet;
4. Feasibility: [7] Industry has the capability and capacity. The RCN and DND has limited capability with its experience on the MCDVs but little to no capacity of scale[41]; and
5. Uniqueness: [8] Plug & fight has been proposed at the strategic level for some time. [42] If such a strategy would be adopted, squadron capability sharing could be a logical evolution. The concept remains at the conceptual strategic level.

The concept scores moderately well in the validity analysis [77%]. Squadron capability sharing will likely be a natural evolution of adopting *distributed effect* strategies. This strategy should be considered an *Essential Strategy* for the RCN.

---

[40] "Modular Warship Concepts: Is 'Plug and Fight' here to Stay?" *Jane's International Defense Review* 46, no. 9 (Sep 1, 2013, 2013a).
[41] A limited number of route survey and mine sweeping packages were initially purchased.
[42] Ongoing internal discussions at RCN Naval Engineering symposiums.

EVOLVED INTEROPERABILITY

Mitigating shrinking fleets is not limited to reducing ones fleet size but can also include joining forces with other likeminded nations. The overarching strategy is not new but evolving requirements in maritime security have necessitated a relook into how it is implemented. Traditionally interoperable task groups consisted of grouping and combining assets from various similarly postured nations. [43] Today maritime interoperability has further evolved to include the following two complimentary strategies: *shared strategic assets* and *foreign capacity building*. These strategies, along with traditional maritime interoperability are considered cost-saving strategies since they indirectly reduce fleet size requirements.

Shared strategic assets consist of nations sharing and contributing to the operation of a given strategic high value asset. The model is akin to the NORAD AWACS model where NATO acquired the platform and contributing nations supply personnel to operate the aircraft. A notable example includes the seventy strong staff of Rear Admiral Jonas Haggren of the Swedish Navy operating from the Royal Netherland Navy's landing platform dock (LHD) *Jonah de Witt* in support of the EU counter Piracy mission "*Operation Atalanta*". [44] The mission also incorporated one Swedish maritime helicopter (MH) and two Swedish CB90 fast patrol craft into the *Jonah de Witt* ship's compliment which were tasked to augment the ship's maritime interdiction capability. The strategy is fairly new in the maritime domain and its effectiveness remains to be seen. Cost-saving benefits include offsetting the cost of major strategic platforms to another nation and potentially reallocating those funds towards other assets that are bilaterally mutually beneficial.

---

[43] Christopher Paul, *The RAND Security Cooperation Prioritization and Propensity Matching Tool*, Vol. TL-112-OSD (Santa Monica, CA: Rand Corporation, 2013a), 5.
[44] Menno Steketee, "Swedish Staff and Equipment Boards Dutch LPD for EU Counter-Piracy Ops," *Jane's Navy International* (January 28, 2015, 2015).

Foreign capacity building consists of a nation providing the ways and/or means to another nation in order achieve mutual ends. [45] The concept envisions supporting and enabling a host nation to first take care of their own maritime security, and hopefully eventually contribute to the security of the global commons. Cost savings occurs when one's own nation no longer needs to supply assets to promote security in support of another nation's security and can re-roll those assets towards other task. The concept aspires for recipient nations to one day become surrogate peer allies capable of increasing the overall global collective fleet size. On any given day there are over 700 warships at sea contributing to maritime security, linking and pooling their capabilities could significantly reduce national requirements for larger fleets. "We talk about a 'thousand ship Navy'. That's not just our ships. It's an international fleet of like-minded nations participating in security operations around the world". [46]

For example, the Australian government announced on June 2014 a $594M AUD Pacific Patrol Boat (PPB) replacement project. The program intends to build 20-22 patrol boats for thirteen Pacific Island Nations. The PPB program has specific negotiated arrangements with each nation but for the most part provides platforms, sustainment and advisory personnel. Host nations provide personnel and operational cost. The program provides Australia the flexibility to employ less RAN personnel while ensuring the same measure of maritime security in the Pacific. The USN has established Southern Partnership Stations (SPS) and African Partnership Stations (APS) with the intentions of capacity building off the waters of Africa and the Caribbean. The initiative has USN assets such as amphibious and sealift ships interacting and supporting host nation minor war vessels. Foreign capacity building, along with strategic asset sharing are

[45] Christopher Paul, *What Works Best when Building Partner Capacity and Under what Circumstances?*, Vol. MG-1253/1-OSD (Santa Monica, CA: Rand Corporation, 2013b), 7.
[46] Admiral Michael Mullen, Remarks made at a town hall meeting in Millington, Tenn. Sept. 7, 2006.

proving to be the catalyst for the evolution of interoperability. Cost-savings occur as investments are distributed or offset.

The RCN has always been highly interoperable with the USN. The RCAF and USAF have an even closer relationship with a shared command structure through NORAD. Collective security may foster the evolution of interoperability. The analysis below investigates evolved interoperability in the Canadian context:

1. Completeness: [8] The RCAF currently operates AWACS with NATO and USAF. Such MOUs can provide precedents and frameworks. That said the strategy has yet to fully materialize in the maritime domain. In terms of building capacity with host nations, the Army is quite involved with building capacity in Jamaica. The Navy can start playing a role in support of Op Caribbes[47];
2. Suitability: [9] This strategy is difficult to determine RCN ROI however if the RCN adopts an AWACs construct, the purchase of a major platforms are not required;
3. Acceptability: [5] The concept is based on sharing risk. Risk does not increase; it is simply distributed amongst nations. Looking at this strategy in isolations, risk should remain the same as the current fleet;
4. Feasibility: [8] NORAD/NORCOM have recently subsumed recognized maritime operating picture responsibilities. This may provide the framework and vehicle to adopt such a construct. Indusrtry (US) and DoD both have the capacity and capability. The RCN currently has the capacity based on retiring five ships and modernizing the CPF;

---

[47] Canadian named operation in support of counter-drug efforts in the Caribbean Sea.

5. Uniqueness: [5] Op REGULUS operationalized the concept to a certain degree by sending a significant amount of RCN personnel on allied platforms[48]. That said, Op REGULUS does not fully meet the intent of Evolved Interoperability.

The concept scores moderately well in the validity analysis [77%]. The RCN has had a taste of Evolved Interoperability with Op REGULUS. NORAD's foray in the maritime domain may also open the door towards the evolution of maritime interoperability. This strategy should be considered an *Essential Strategy* for the RCN.

> No matter how large or small your navy or coast guard may be, we all face similar internal constraints like shrinking budgets, aging equipment, and populations that may not be attracted to military service. Our level of cooperation and coordination must intensify in order to adapt to our shared challenges and constraints. We have no choice in this matter, because I am convinced that nobody - no nation today - can go it alone, especially in the maritime domain. [49]

Distributed force cost-saving strategies are all about distributing risk. Investment and sunk cost remain largely the same as traditional battle force models however; variations in force quantity, structure, composition and attributions allow flexibility in employment and operations that could yield significant through life cost savings. Most of these concepts are in their infancy and lack sufficient data point to estimate cost-savings. Distributed force cost saving strategies on their own are difficult to achieve, they rely on complimentary cost-saving categories such as Distributed *Effects*, *Sustainment* and *Acquisition* in order to harness their full potential.

---

[48] RCN named operation intended on executing large scale employment of RCN personnel on allied ships due to lack of sea going platforms available for training.

[49] Admiral Michael Mullen, 17th International Seapower Symposium, 21 Sept. 2005, Newport, R.I.

CHAPTER 2: DISTRIBUTED EFFECT

The concept of distributed effects aspires to balance, share and disperse traditional organic shipboard capabilities in a cost-effective manner. Modern maritime warfare is fought in four domains (air, surface, subsurface and cyber). Platform centric warfare compels a single ship to organically possess a myriad of systems in order to prevail in all warfare domains. The traditional 35-year platform service life and today's pace of innovation are increasingly encouraging navies to find ways to offload or share capabilities in the hopes that their platforms remain relevant through life. Distributed effects aims to share and offload capabilities through *Plug & Fight Modularity*, *Unnamed Vehicles (UV), Smart-Kill*, *Net-Centric Warfare (NCW)* and *Naval Gun Fire Support (NGFS)*. Most of these concepts complement each other and cannot be fully effective without capabilities resident in another. Sharing and offloading capabilities amongst platforms permits cost-savings by moderating the number of systems resident on each ship. Distributed effects decouples capabilities from ships as a platform. Essentially ships could then be designed as capability carrying platforms akind to aircraft carriers but on a smaller scale.[50] Decoupling seaframes and capabilities permits ships to maintain long life-cycles while remaining relevance through life.

PLUG & FIGHT MODULARITY

Plug & fight mission packages consist of containerized systems that quickly integrate into ship's hotel services. These packages provide effects in a particular warfare domain. They are intended to be organic and therefore remain on-board. Modularity allows ships to be reconfigured based on mission requirements and reduces the need for expensive multi-role ships.

---

[50] Geoff Fein, "USN Official Says Surface Ship Designs must be More Flexible to Maximise Service Life," *Jane's Navy International* 120, no. 4 (May 1, 2015, 2015a).

The concept permits for cost effective future capability insertion as well as the aforementioned *squadron capability sharing*. Navies no longer need to purchase corresponding systems for each platform eliminating duplication and maximizing usage.

Mission packages trace their origin to the early 80s when the Danes needed a cost-effective framework that would permit the replacement of 22 minor war vessels (6 torpedo boats, 8 minesweepers and 8 patrol boats). Studies indicated that those 22 vessels could be replaced by 16 reconfigurable ships. [51] The initial impetus for the STAN FLEX architecture was merely cost-savings at acquisition since a one-for-one replacement of 22 legacy vessels was deemed unaffordable. Figure 7 illustrates a Stan Flex mission module change out.

Figure 7- STANFLEX Change-Out
Source: Jane's International Defence Review, Modular Warship Concepts: Is Plug & Fight here to stay?

Today studies indicate savings associated with operations and maintenance far exceeds those gained during acquisition. [52] The argument was compelling enough for the USN to hedge 25% of their fleet to the concept. A 2004 CSBA report estimated that 56 LCS with plug & fight

---

[51] "Modular Warship Concepts: Is 'Plug and Fight' here to Stay?"
[52] Ibid.

mission packages would be equivalent to 77 multirole ships providing a **38%** fleet strength increase. [53] The USN had originally planned on procuring 64 mission packages (16 ASW, 24 MCM, 24 ASuW) negating the need to purchase, maintain and operate 156 (3x52) individual system required in a traditional multi-role ship construct. The number of mission packages is currently under revision based on the recent announcement from NAVSEA to "up-gun" the last 20 LCSs closer to a frigate variant. The RN has recently announced entering the demonstration phase of their Type 26 Global Combat Ship (GCS). The Type 26 is intended to be a one-for-one replacement of 13 legacy Type 23 frigates. The GCS will incorporate a large flexible mission space amidships capable of accepting various standard ISO containers supported by a common hotel service grid system. The mission space, along with flexible accommodation modules permit the RN to maximize on the MoD's nineteen destroyer/frigate cap derived in 2010's Strategic Defence Security Review (SDSR). [54] ThyssenKrupp Marine Systems (TKMS) is also introducing mission packages to their MEKO family of ships. Their MEKO CSL corvette will have space for up to seven ISO 20 containers forward, eight amidships and six back aft. The MEKO family, arguably the most successful export variant in the modern era, will likely prove to be the catalyst for wide acceptance of plug & fight.

The primary trade-off with plug & fight is the added premium associated with delivering such a framework. A RAND study estimates a 0.77% long term premium to the entire LCS program associated with added infrastructure requirements necessary to implement modularity. [55] The RDN highly favours utilizing STAN FLEX packages for maintenance purposes rather than

[53] Work, *Naval Transformation and the Littoral Combat Ship*, 122.
[54] Richard Scott, "UK Defence Chief Vexes on Fleet Size, Capability," *Jane's Navy International* 118, no. 1 (Feb 1, 2013, 2013).
[55] Brien Aikire, *Littoral Combat Ships: Relating Performance to Mission Package Inventories, Homeports, and Installation Sites* (Santa Monica, CA: RAND Corporation, 2007), 60.

reconfigurability. [56] Ships for the most part kept their standard configuration. STAN FLEX modules remain at home port and rarely forward deployed. In RDN's case the premium associated with the framework needs to be weighed against the benefits gained by controlled maintenance.

RAND estimates that mission modules account for 23.2% whereas seaframes account for 67% of overall project cost. These figures are in sharp contrast to the 50% traditionally allocated to fixed non-modular systems. Appendix I illustrates traditional cost breakdown by component. Note how combat systems alone account for 50% of build cost yet only 11% of weight. [57] By their very nature not all fixed systems can be made modular making a true one-for-one trade-off comparison difficult to conduct. The study also emphasises the additional logistical footprint required to coordinate and sustain a plug & fight modular architecture.

ROI associated with a Plug & Fight architecture are fourfold. Firstly, reconfigurability and flexibility account for a 38% increase in force strength. [58] Secondly reduced capability based acquisition cost. Navies are no longer required to purchase multiple systems for every platform. Mission packages allow navies to purchase just enough systems to cover the amount of seaframes in their inventory. Additionally capability insertion and midlife upgrades are decoupled from the seaframe reducing risk to midlife extensions. Ships could feasibly sail without any mission packages depending on the mission. Thirdly, reduced lifecycle O&M cost; mission packages allow navies to perform maintenance in environmentally controlled settings potentially increasing the lifespan of the packages. This maintenance approach also decouples

---

[56] "Modular Warship Concepts: Is 'Plug and Fight' here to Stay?"

[57] Weight is an important consideration when evaluation the potential for modularity. Systems must be crane transportable in order to be interchangeable

[58] Work, *Naval Transformation and the Littoral Combat Ship*, 122.

seaframe overhauls from equipment overhauls. Lastly, reduced organic capabilities implies reduced crew sizes compared to multi-role ships which ultimately reduces overall operating cost.

The following analysis will employ the same 38% platform bonus metrics employed by the RDN and USN gained by the employment of a plug & fight architecture. The analysis also assumes that only CSC (AOPS to a limited extent) ships can still potentially incorporate a plug & fight architecture:

1. Completeness: [9] The architecture has been proven operational with the RDN on a smaller scale and is currently being tested by the USN on a macro scale. The technology is assumed to be mature once CSC and AOPS roll out;
2. Suitability: [9] The architecture would provide the equivalent of 21 CSCs, or 6 additional platforms yielding a significant ROI against inflation. Note that current RCN practice includes a significant amount of TRANREQs[59] in order to meet operational requirements. TRANREQs can account for a fourfold increase in cost & resources that would not be applicable in a Plug & Fight Architecture;
3. Acceptability: [9] CORA ran simulations incorporating 16-30 platforms with combinations of patrol, Destroyers and General Purpose Frigates yielding results exceeding 100% risk reduction. In fairness the simulation does not really correlate directly with Plug & Fight but is applicable to the analysis of 21 virtual CSCs vs 12 CPFs;

[59] Transfer Requirement (tranreq), unpurposeful removal of a system from one platform to another in order to meet operational requirements. Cost include removal off one platform, installation on the other, test & trial on new platform, and removal followed by re-installation on first platform, and finally test & trial.

4. Feasibility: [7] US and Danish industries have the capability and capacity. The RCN and DND has limited capability with its experience on the MCDVs[60]; and
5. Uniqueness: [5] Currently being analysed as part of the CSC project however no public statements have been made calling for a plug & fight requirement (as opposed to type-26 and LCS who publicly stated requirements from the onset). MCDV have limited plug & fight capability which probably never truly reached FOC and could be considered relatively inconsequential to uniqueness.

This strategy scores quite highly in the validity analysis [86%] and supports the continual allied adoption of this cost-saving strategy. CORA's studies note that an increased amount of combatant platforms require additional AOR support or else overall risk significantly increases. It is unknown if the *virtual* additional platforms would require the same amount of underway support. Further analysis is required to determine the true cost of TRANREQs in comparison to a plug & fight architecture. This strategy should be considered a *Critical Strategy* for the RCN.

UNMANNED VEHICLES

Unmanned vehicles are colloquially referred to performing 4D missions –Dull, Dangerous, Dirty and Deep. Conceptually UVs are inorganic autonomous or semi-autonomous mission packages capable of augmenting seaframe organic capabilities. UVs can be interchanged between platforms permitting similar cost saving features as in a plug & fight architecture. The major difference lies with the 4D unique properties.

---

[60] The RCN employs seven different types of mission modules (seventeen in total) mostly dedicated for route survey and minesweeping duties. See Janet Thorsteinson, "Modular Warships," *Canadian Naval Review* 8, no. 4 (2013). http://www.navalreview.ca/wp-content/uploads/public/vol8num4/vol8num4art7.pdf.

Cost-savings associated will the *Dull* property revolves around reducing crew sizes. Data collection in the maritime domain is resource intensive requiring persistence and diligence in order to discriminate targets from the environment. Autonomous UVs can remain to task for long durations freeing humans to analyse, interpret and act on the data. Re-aligned watch rotation could reduce the size of Combat Departments. [61]

UVs do not require life support systems which permit effects to be generated in austere environments. Additionally space made possible by lack off life support systems translates into increased payload capacity potentially extending range or adding onboard capabilities. Unnammed Underwater Vehicles (UUVs) hold the potential to replace or reduce submarine fleets, significantly lowering overall fleet acquisition cost. [62] Figure 8 illustrates the NATO MUSCLE autonomous vehicle being trialed off the coast of La Spezia, Italy.

Figure 8-NATO's MUSCLE AUV and the research vessel NRV Alliance
Source: Jane's Navy International, Keeping a Cutting Edge

[61] Similarly robust UAVs could reduce the size of the Air Departments. Task Groups could be reorganized in such a manner that one manned helicopter is shared between platforms and UAVs augment the task group's air requirements.

[62] The USN's Chief of Naval research states that their Large Displacement Underwater Vehicle (LDUUV) aims to significantly revolutionize underwater warfighting. Geoff Fein, "USN S&T Research Strategy to Focus on New Weapons, Unmanned Systems, and Cyber," *Jane's Navy International* 120, no. 4 (May 1, 2015, 2015b).

Appendix J demonstrates employing UVs in depth. Being offboard permits depth between effector and platform permitting considerable advantages to the five command functions (sense, act, shield, sustain and command).[63] Depth in *Sense* provides early warning during the *detect-to-engage* sequence potentially reducing salvo size requirements and reducing cost associated with using expensive ordnance to defeat threats. Depth in *Act* provides the ability to penetrate environments such as the littoral while remaining in more permissive environments. Cost savings occurs by reducing the need for classes of ships tailored for the littoral, facilitating the acquisition of a more homogenous cost effective fleet. Depth in *Shield* provides the ability to seduce, confuse and disrupt incoming threats at stand off from their more expensive seaframe. Depth in *Sustain* permits the prioritization of manned vehicle towards mission essential task while diverting UVs towards sustainment. Persistent underway replenishment by UVs could allow the seaframe to stay on station saving fuel required for transits in/out of theatre which ultimately could reduce the number of seaframes required for persistent deterrence measures. Depth in *Command* permits a robust and resilient C^2 structure with UVs providing range extension and redundancy to a meshed net-centric architecture. Figure 9 illustrates a RAND proposed concept of operation for UAV relays.

[63] Canadian Forces College and College des Forces Canadiennes, *CFC Guide to CF Operational Planning Process*

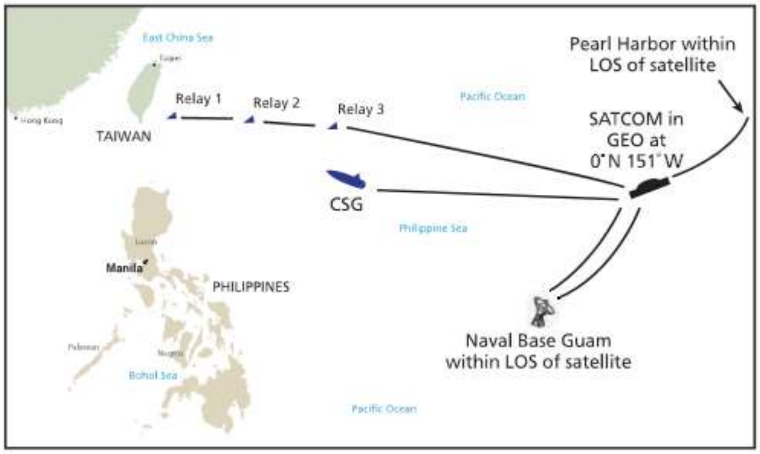


Figure 9-CONOPs for Theatre Relay Application
Source:Alkire,"Applications for Navy Unmanned Aircraft Systems",36.

Cost saving would occur when UVs facilitate information dissemination reducing the numbers of platforms required to perform the same task. Simply put, most allied navies are going unmmaned. Appendix K illustrates the technical maturity of allied navies' USV ambitions. Note how endurance and payload remain relatively low throughout. Research in next generation USVs is dominated by the USN. [64] USVs remain the emphasis of this analysis since UUV maturity is relatively low and maritime specific UAVs are limited to a handful of platforms, namely the USN Fire Scout family. Figure 10 illustrates Technology Readiness Level (TRL) 8 or above USVs per country whereas Figure 11 illustrates USV applications currently in the marketplace. Both figures highlight the emerging depth and diversity of the market place as well as the universal trend towards adopting UVs.

[64] The USN is taking unmanned systems so seriously that they have setup an entire office (deputy assistance secretary) to oversee all unmanned activities. This brings UV warfighting at the same level as other warfare domains in the USN. Jean Grace, "Navy League 2015: USN Establishing Office to Oversee Unmanned Systems," *Jane's Defence Weekly* 52, no. 22 (Apr 15, 2015, 2015a).

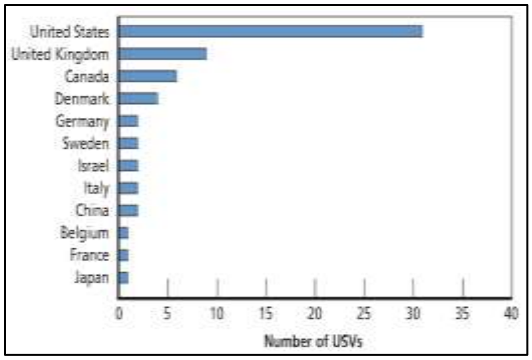


Figure 10 Numbers of USVs at TRL8 by Country
Source: Savitz, "US Navy Employment Options for Unmanned Surface Vehicles",11.

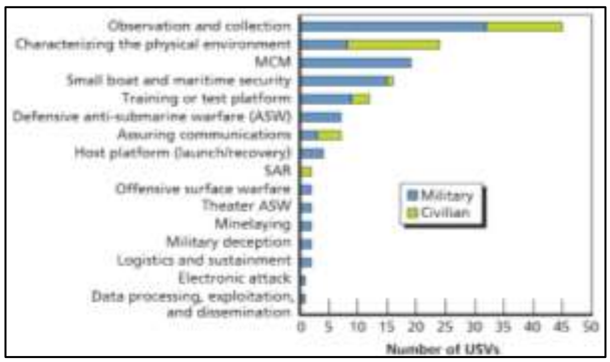


Figure 11 Number of USVs by task in marketplace
Source:Savitz, "US Navy Employment Options for Unmanned Surface Vehicles",11.

Intuitively the ROI for incorporating a UV infrastructure resembles that of organic mission packages with the added benefit of potentially reducing fleet and crew sizes. Seaframe sophistication can be deemphasized and risk can be offset to unmanned platforms. UVs remain an attractive cost-savings strategy for navies who are compelled and limited to retain limited high end platforms while concurrently maintaining a *quantity as a quality* disposition.

The following analysis will employ the same 38% platform bonus metrics employed by the RDN and USN gained by employing a plug & fight architecture. For simplicity the analysis equates organic mission packages with inorganic mission packages. The analysis also now assumes that CSC, AOPS, JSS and to a limited extent CPFs and MCDVs can partake in a UV architecture:

1. Completeness: [7] Land-based UAVs have been proven operationally in the maritime domain during the Libyan campaign but UUVs and USVs have yet to reach their full potential . Furthermore UAV assets are in limited adhoc capability and quantity in the RCN. No formal architecture currently exists in the RCN;
2. Suitability: [9] A generous assumption is that the architecture would yield a 38% increase in platform. The true ROI is unknown. The real benefit for the RCN is the fact that this architecture could supplement the limited combat capability of AOPS and JSS. UVs will be an important asset to Artic surveillance and could easily mitigate the proposed reduced number in AOPS hulls. UVs hold the potential of providing air power to the MCDVs, significantly increasing their reach and flexibility during Caribbean counter-drug operations. This architecture might also mitigate TRANREQ creep[65];
3. Acceptability: [9] Again, CORA ran similar simulations incorporating 16-30 platforms with combinations of patrol, C^2 and General Purpose Frigates yielded results exceeding 100% risk reduction;
4. Feasibility: [9] Canadian industry has the capability and capacity through companies like Meggitt, L3 Wescam and Innovator Technologies. The RCN has operational experience with the Scan Eagle, and DND has started to setup various teams to tackle UVs at large. Of note, NSPS should incorporate a USV component in order to leverage and support the

[65] Tranreqs would be minimized since UVs are modular. A damaged organic system from one ship could be supplemented by an equivalent UV. For example rather than taking a functional sonar from one ship to support another's operational requirements, an additional UUV could be added to the recipient ship.

nation’s current industrial base. A recent RAND study suggest that Canada is ranked 3th worldwide in USV production and development[66]; and

5. Uniqueness: [5] Land based UAV systems have been operationally adapted for maritime use. DRDC has recently trialed rotary wing UAVs and unnamed ground vehicles (UGV) in support of Artic surveillance. Figure 12 illustrates both systems being trialed at CFS Alert in the high Arctic. Furthermore, sonaboys have been in operation for quite some time now. They are not comparable to fully automated UVs but offer sensor depth and reach to the organic platform similar to UVs.

Figure 12- DRDC UAV and UGV under development
Source: Government of Canada Press Release, “Scientific Team Returns from Experimental Mission in the Arctic”.

The strategy scores quite highly in the validity analysis [86%] and supports the continual allied adoption of this cost-saving strategy. DND holds a unique opportunity to leverage off of the nation’s burgeoning UV market and should continue to invest and partner in the area. This strategy should be considered a *Critical Strategy* for the RCN.

[66] Scott Savitz et al., *U.S. Navy Employment Options for Unmanned Surface Vehicles (USVs)*RAND, 2013), 11.

SMART-KILL

> *Not everything can be an exquisite multimillion-dollar missile that goes down range. We have to do the right-cost weapons, [and they] have to go out for the right threat. Some of that might be a cyber-effect.*
>
> -Admiral P. Davidson, Commander US Fleet Force Command[67]

Simply put, hard kill is expensive and naval warfare is attritional. Ammunition alone accounts for 12 % of ship cost with an average *cost-per-round* of $1M USD for defensive and $5M USD for strike guided weapon systems.[68] Furthermore these systems cannot be replenished at sea and often require supporting guidance systems in order to operate. The ability to leverage off of soft kill and direct energy weapon's *low cost-per-round* is indeed the cost-saving strategy at hand.[69] The issues isn't about de-emphasising hard kill but rather striking the right balance so that threats are prosecuted or defeated with *cost-appropriate* measures.

The USN will soon introduce the Surface Electronic Warfare Improvement Program (SEWIP) Block 3 aimed at significantly upgrading and integrating transmitters, arrays and processing techniques. The system is based on the Transportable Electronic Warfare Module Program (TEWMP), a modular technology demonstrator created by the Naval Research Laboratory (NRL). The USN has also recently operationalized the first technology demonstrator of its Naval Laser Program. The 30kw system laser weapon system (LaWS) onboard USS Ponce is estimated to cost 1$ per round. The RN and MN are jointly developing an active maneuvering

---

[67] Jean Grace, "Surface Navy 2015: Future Threats Will See Surface Forces Recoup Offensive Capability, Says USN," *Jane's Navy International* 120, no. 1 (Feb 1, 2015, 2015b).
[68] Canada. Department of National Defence, PMO CSC, *Options Analysis Brief to CMS* (Ottawa Canada: , 2009).
[69] Soft kill entails defeating inbound threats with non-kinetic means such as Radio-Frequency (RF) jamming, flares or acoustic counter-measures. Hard kill involves defeating threats by propellant or energetic means such as missiles and projectiles.

RF anti-ship missile countermeasure. The Technology Demonstrator Programme named ACCOLADE is scheduled to finish testing in 2015. [70]

Capability tradeoff associated with a hard-soft kill balance is mostly based on perceptions (misconceptions). Soft Kill based technologies are often deemed less attractive because it is difficult to put faith in systems that are intangible, complex, secretive and seldom tested. In contrast hard kill is kinetic, tangible and relatively easy to comprehend: “you shoot at me, I shoot back”. If anything a hard kill centric platform is cost prohibitive and may result in capability trade-offs in other areas. In contrast, the ROI with a well-balanced hard-soft mix means costs are reduced and capability trade-offs mitigated. The following analysis will evaluate if indeed the RCN requires a relook into their soft-hard balance of weapon systems: [71]

1. Completeness: [8] Organic soft-hard balance has a well-established operational record [9] however inorganic soft-hard balance is just entering demonstrations [7]. Inorganic options must be considered in this assessment in order to truly leverage the cost-savings benefits of soft-hard balance. Furthermore, direct energy weapons are also just entering demonstration phase [7] and as previously discussed will play a significant role in cost reduction;
2. Suitability: [3] Considering ordnance cost on average 12% of shipbuilding cost, full optimization of a soft-hard balance could never yield significant cost savings on

[70] Richard Scott, "UK Looks to Examine Enhanced Active Soft-Kill Decoy," *Jane's Defence Weekly* 52, no. 9 (Jan 14, 2015, 2015).
[71] The RCN’s current above water hard kill capabilities include SM-2, and ESSM. Anti-submarine weapons include mk46 and mk48 torpedoes. Anti-surface weapons include Harpoon. Gun systems include 20mm CIWS, Bofors 57mm mk III and Oto Molera 76mm Gun Systems. Organic softkill includes Nixie for ASW, RAMSES and MASS for AAW. The RCN no longer has any inorganic softkill capability. ESSM blk II is currently under development and the government has endorsed continued participation in the program. Current estimates suggest $6M per missile. There are no programs of record for Harpoon upgrades. SM-2 service can be extended to meet CSC IOC. RAMSES is no longer supportable and requires a replacement. Source: Director General Maritime Equipment Program Management, Project Directive Briefing, 2014.

acquisition. That said ordnance is a perishable items that is either used or refreshed. This analysis does not account for the true lifecycle cost of ordnance on a warship;

3. Acceptability: [6] It is difficult to determine whether or not a shift in soft kill would be riskier. Optimistically they would meet the same risk threshold but lower the lifecycle cost of a fleet. CORA's *Option 3* of their fleet mix study II suggest roughly a 25% increase in risk compared to the current fleet. Their option 3 fleet has no Area-Air Defence platforms and composed mostly of patrol and general purpose warships with very limited hard kill capability. There is no mention of softkill. The fact is, even after removing virtually all true hardkill from the fleet, at significant cost reduction, risk increase is not commensurate with the cost savings;
4. Feasibility: [9] Industry, DND and the RCN fully have the capacity and capability to pursuit a more balanced soft-hard kill mix. UV based inorganic soft kill would be new to the RCN and would require some operational and tactical development. Industry is ready to support such an evolution; and
5. Uniqueness: [6] Above Water soft kill is fully enshrined in operational tactics. That said, inorganic softkill is not. The RCN flirted with the Nulka inorganic soft kill hovering rocket for roughly 10 years but gave up due to supportability issues. Additionally, soft kill in anti-submarine warfare has been employed in the RCN for some time.

This cost-saving strategy is of moderate impact scoring 71% in validity. The RCN has a high likelihood of naturally gravitating towards this strategy based on the aforementioned emerging technologies. This cost-saving strategy is an *Essential Strategy* for the RCN.

NET-CENTRIC WARFARE

Netted warfare in the maritime domain is all about sharing, compressing and synchronizing effects. Net-Centric Warfare (NCW) is considered a cost-savings strategy because of the organic systems trade-offs that it permits without the associated consequential capability trade-offs. NCW permits a meshed recognised maritime picture by enabling platforms to share their raw organic sensor data with others. Consequently not all platforms require expensive high-end sensors in order to see the same picture.[72] Additionally, sensing fidelity, reach and depth can be extended by off board systems further reducing the cost of organic systems. Netted meshed platforms sharing the same picture can also coordinate reactions much quicker compressing the *detect-to-engage* sequence. Cost-savings occurs by mitigating one's own collateral damage and reducing salvo-sizes utilized to counter threats. NCW does not require all platforms to carry ordnance enabling cooperative engagement synchronization. Cooperative engagements lower cost by virtue of some platforms carrying less or no ordnance. Synchronized engagements lower cost because they permit to do more with less. Salvo sizes are again reduced by selecting and sequencing the best engaging platform.

There are two main NCW architectures being developed and utilized by allied navies. Cooperative-Engagement-Capability (CEC) developed by the USN is currently operational and fielded on a significant number of their surface and air assets. The RN has recently dropped CEC in order to control the spiralling cost of their Type 45 program.[73] The CEC architecture was initially intended to mitigate the loss of reducing the size of the type 45 fleet. The RN CEC program was estimated to cost £24M per ship. The other architecture, Capacité d'Engagement

---

[72] Brian Clark, "Commanding the Seas: A Plan to Reinvigorate US Navy Surface Warfare," *CSBA* (2014), 16.
[73] Thomas Harding, "Cutting Missile System Leaves Warships at Risk [Edition 2]," *The Daily Telegraph*Jun 9, 2012, 2012.

Multi Plate-forme (CEMP) is being developed by the DGA. [74] La Marine National and DGA continue to mature their architecture in the hopes of providing allied nations an alternative to CEC.

NCW may entice navies in offsetting capabilities to high end platforms causing them to become critical points of failure. The resultant capability trade-off becomes the reliance of some aspects of *Distributed Force* such as *squadron capability sharing*, potentially at the detriment of fostering *Distributed Effect*. Conversely a robust NCW architecture enables all strategies of *Distributed Forces* and is essential for operating UVs as distributed nodes.

The following analysis will focus on CEC since it is the premier NCW architecture currently in operations. As previously discussed CEC Cooperating Units (CUs) share a common air picture. CEC would feasibly allow the RCN to have fewer high end Area Air Defence CUs and more General Purpose arsenal ships. Recall CEC cost the RN £24M per ship or $50 million CAD. The architecture could be applied to all RCN ships but most applicable to the CSC variants:

1. Completeness: [9] The architecture has been proven operationally with the USN for track fusion. On 24 Oct 2014 the USN successfully completed a cooperative engagement where USS Chancellorsville shot down two cruise missiles targets spotted by USS Sampson[75];

[74] Director Général d'Armement: French procurement and equipment management directorate.
[75] Sydney Freedberg, "You Spot I Shoot: Aegies Ships Share Data to Destroy Cruise Missile," Breaking Defense, http://breakingdefense.com/2014/10/you-spot-i-shoot-2-navy-aegis-ships-with-sm-6-kill-target-together/.

2. Suitability: [9] A 2009 CSC Options Analysis (OA) Study compares costing of various fleet mix options. The report compares three ship class profiles. [76] The presentation goes on to suggest that the RCN can afford seven *profile 1* ships at a cost of $25.5B CAD. At a very minimum one *Profile 1* ship would be required per coast in order to make a CEC architecture work. The report then suggests that the RCN could afford two *Profile 1* and eight *Profile 2* ships for 25.6 Billion totalling ten platforms. Now let us reconsider the added benefits on CEC. The RCN could yield a *36.4%*increase in platforms for roughly the same price, fully acknowledging that not all capabilities would be equivalent but the analysis highlights ROI suitability[77];
3. Acceptability: [9] CORA's Fleet Mix II study compares three different fleet mix options. Figure 13 illustrates the results. Of particular note are fleet mix *options 1* which comprises three Air-Defence destroyers and twelve general purpose frigates (GP), *Option 2* is comprised of fifteen GP CSCs commensurate with the platform bonus offered by CEC. Each option yields at least a 30% reduction in risk compared to the current fleet;

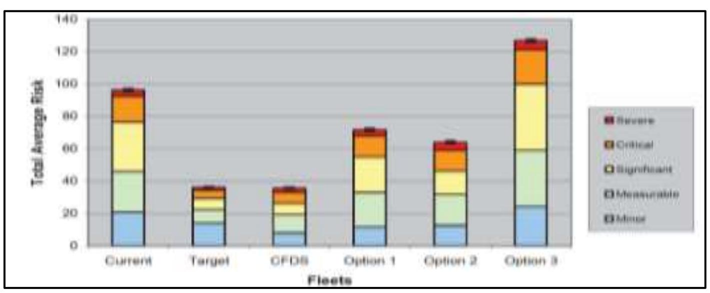


Figure 13- Comparing total risk of cost equivalent fleet options
Source: Bourque, Eisler, "CORA Fleet Mix Study Iteration II", 42

---

[76] Profile 1: Full command and control air defence ship comprising Vertical Launching System (VLS) and a Active Multifunction Radar (MFR). Profile 2: slightly slower, has SAMs but no VLS or Active MFR. Profile 3: limited combat systems and does not apply to the analysis. CEC would extend the Profile 1's MRF capability to the Profile 2 ships and their increased numbers would mitigate the reduced overall fleet missile arsenal carrying capacity from the loss of VLS associated with profile 2. See Canada. Department of National Defence, PMO CSC, *Options Analysis Brief to CMS*

[77] 7 non-CEC ships at $25.5B vs 12 CEC enabled ships $25.6B yields roughtly a 36.4% increase in platforms. The analysis subtracts one platform to account for the cost of CEC ($50M/ship)

4. Feasibility : [8] Industry has the capability and capacity. The RCN and DND only have the capacity to implement such an architecture but lack technical capability. The RCN has employed the ADSI capability on their destroyers in the past and could easily transition into a CEC framework[78]; and
5. Uniqueness: [7] CEC is mentioned in all RCN future doctrine but has yet to be operationally tested. The RCN purchased a try & buy "listen-only" module of CEC for RIMPAC 2012 but due to time constraints were unable to install and test.

The strategy scores quite highly in the validity analysis [93%] and supports the USN's transition towards a Total Force Battle Network. [79] Further operational analysis is required to wargame Above Water Warfare scenarios in order to validate assumptions about Profile 1 vs Profile 2 equivalency with CEC. Interestingly, operational interoperability with the USN may simply dictate the requirement for CEC. As such, this strategy should be considered a *Critical Strategy* for the RCN.

NGFS

Naval Gun Fire Suport (NGFS) as a cost-savings strategy emphasizes surface seaborne strike and deemphasizes land or air based fire support. Cost-savings with NGFS are both direct and indirect. NGFS directly decreases cost by reducing the need to use expensive land attack missiles (LAM) such as Tomahawks and Storm Shadow, especially against less than high value targets. Recall the imperative for choosing right cost weapons. That said, land attack missiles'

[78] Air-Defence Systems Integrator (ADSI) was a trial system employed on HMCS Algonquin throughout the 2000s. The system enabled easier link-16 sharing of data.
[79] Work, *Naval Transformation and the Littoral Combat Ship*, 14.

operational range far exceed that of even the best extended range guided rounds. The decision to choose either modality is based on tactical requirement however the choice to keep using either one is very strategic. Today's land attack missiles have a range of 1000nm but cost $1.6M USD. Fix wing Close Air Support (CAS) cost on average $30k/hour or $350k/mission. Appendix L illustrates a breakdown of CAS cost in Afghanistan per airframe. In contrast, extended range guided rounds can go beyond 60nm but cost 50kUSD. NGFS indirectly decreases cost by virtue of the low logistical footprint surface ships possess in comparison to land or air based fire support. No additional air defence, mobility constraints, shield elements, airbases or carriers are required. The comparison between NGFS, close air support and LAMs are caricatural as their capabilities vastly differ. The point being right cost weapons offer significant cost savings potential.

> Land-sea missile attacks have added to the already prevalent strikes by aircraft to and from the sea to blur the tactical distinction between sea and land combat…Perhaps the navies of the world should no longer refer to "naval" tactics at all. It is more reasonable to think in terms of littoral tactics that include warshships. [80]

The three main champions of extended range guided NGFS are the USN, the German Navy and the Italian Navy by means of Raytheon and OTO Melara systems. Raytheon is set to conduct live fire test mid-2015 of their N5 Excalibur rounds. The round is said to have a range of 60nm and cost $50k fired from a Mark45 mod 4 deck gun. OTO Melara is currently testing its 127mm extended range Vulcano round which has a range of 60nm and cost 30k€. OTO Melara is also developing a 76mm variant with an advertised range of 25nm.

[80] Hughes, *Fleet Tactics and Coastal Combat*, 11.

Capability trade-offs compared to a traditional land attack missile include range, target discrimination, battle damage assessment and lethality. NGFS does however provides a theater commander the ability to strike in depth medium to low value targets without needing too many direct and supporting resources. During the Lybian campaign the USN fired 150 TLAMs with 1000lbs warheads against targets such as SAM sites and C2 nodes near or about the shoreline. NGFS could have prosecuted most of those targets at a vastly reduced cost. NGFS could have also enabled navies without land attack or carriers to participate in direct actions which could have had significant political, strategic and operational ROI. The following analysis investigates if NGFS is an applicable cost-saving strategy for the RCN:

1. Completeness: [9] On 6 Mar 2014 the German Navy completed operational testing of their 127mm Vulcano rounds marking the first time since WWII that a naval ship has reached such ranges;
2. Suitability: [9] The RCN has no true Land Attack Missile capability (harpoon in very limited) therefore NGFS will only be compared to CAS. [81] Cost savings should be viewed pan-CAF. The Parliamentary budget office estimates that Op Impact cost $166M for 6months in Iraq[82]; the bulk of the cost being attributed to the 6 pack of CF-18s that flew 320 sorties in 6 months. Recall Appendix L, a bombing sortie costing $350k USD or $112M USD for Op Impacts sorties thus far. Assuming it takes fifteen127mm Vulcano

[81] Harpoon can strike land targets via GPS terminal guidance only however does not have terrain or target recognition capabilities limiting angles of approach and topographically challenging scenarios (Harpoon was designed as a sea-skimming weapon, on-board altimeter can compensate for topographical features to a limited degree).
[82] Canadian named mission in Iraq and Syria against ISIL.

round to equate the lethality of one 1000lbs GBU-32 JDAM.[83] From 2 Nov 2014 to 22 Mar 2015 CF-18s hit 50 ISIL targets, most soft skinned positions.[84] A frigate employing NGFS to prosecute those targets over 5 months would have cost $45M[85], in sharp contrast to the $112M. Similarly the Libyan mission cost $347M which included again a six pack as well as a frigate with very limited land attack capability.[86] The point being, the comparative cost between CAS and NGFS far exceeds ROI and is applicable beyond Navy lines;

3. Acceptability: [9] CAS requires Air Superiority and is at risk to even rudimentary anti-air measures. Land based indirect fire is at risk of enemy counter-fire. Comparatively speaking NGFS is at a far lower risk spectrum then conventional measures in the CAF;
4. Feasibility : [9] General Dynamic Ordinance and Tactical Systems (GDOTS) is a prominent defence contractor with vast experience in reproducing OEM sourced munitions.[87] The Canadian Army and DND have the capacity and capability from usage and procurement of guided munitions in Afghanistan to help the RCN implement such an architecture; and
5. Uniqueness: [6] NGFS is in CSC's statement of requirements (SOR).[88]

The strategy scores quite highly in the validity analysis [93%] and supports CSC's inclusion in its SOR. The RCN should consider repurposing its four legacy 76mm

---

[83] Rudimentary estimation based on a 68lbs Projectile (35lbs warhead), 15 rounds will have significantly more fragmentation but less over-pressure then a JDAM, lethality is truly target dependent. Estimations based on calculations made during my MSc in Guided Weapon Systems, Cranfield University.
[84] Canada. Department of National Defence, "Operation IMPACT: Air Task Force-Iraq Airstrikes," http://www.forces.gc.ca/en/operations-abroad-current/op-impact-airstrikes.page.
[85] Estimate based on : (150 days @ 50k/day= $7.5M) + (50 targets requiring 15 Vulcano rounds= $37.5M).
[86] The analysis under emphasizes the flexibility brought by CAS and the littoral limitations of NGFS, the point being, if the conditions are right, NGFS is far more cost effective
[87] GDOTS has successfully reproduced Bofors 3P ammunition for the 57mm MkIII gun.
[88] Canada. Department of National Defence, *Statement of Requirements: Canadian Surface Combatant Draft*, 2014).

decommissioned from the IRO class for AOPS or the Halifax Class as a primer for CSC. This strategy should be considered a *Critical Strategy* for the RCN.

Distributing Effects disperses cost and deemphasizes the sophistication of the seaframe. Simplifying seaframes decouples capabilities from delivery systems permitting more predictable service life for seaframes and capability based systems. Organic and inorganic mission modules allow flexibility in scalability which can yield significant cost-savings when planning force structure. *Smart-Kill, NCW* and *NGFS* enable UVs to realize their full potential as a cost savings strategy. Again, like *distributed force,* the elements of *distributed effects* could yield significant cost-savings if used in tandem and can yield even better results if used in conjunction with the elements of *distributed sustainment*.

CHAPTER 3: DISTRIBUTED SUSTAINMENT

"Much of the debate about LCS centres on its sticker price. It is important to note, however, that about 70% of a ship's total ownership cost comes after construction and is driven by operations, modernisation, and people".[89] Distributed sustainment seeks to reduce cost of operation & maintenance (O&M) by lengthening and sharing the burden of costly activities throughout the Naval Enterprise.[90] The underlying theme behind distributed sustainment entails improving a ship's sea-shore ratio. Appendix M illustrates the cost breakdown associated with procurement, personnel, fuel and maintenance for each of the USN's surface fleet classes. The USN estimates that a surface ship provides 4.5 months of presence in a 24 month cycle which equates to requiring five ships for each one forward.[91] Consequently, improving a ship's sea-shore ratio not only reduces the number of hulls required by a fleet, but also the overall O&M associated with a reduced number of hulls. Maritime presence at sea requires platforms, people and fuel. *Program re-adjustment*, *Forward Staging and Flexible Crewing* aim to get the best use of platforms, people and fuel.

PROGRAM RE-ADJUSTMENT

Program re-adjustment seeks to maximize the operational availability of ships by strategically adjusting their cycles.[92] Minimizing transit time is addressed in *Forward Staging* and *Flexible Crewing* sections. Maximizing ToS was covered in *Distributed Force* as well as the

---

[89] "Opinion - LCS: The US Navy's 'Disruptive' Warship."

[90] *Naval Enterprise* consist of industry, the naval institution, and government (departmental organization, supporting agencies and political body)

[91] Jino Choi et al., *Improving Navy's Buying Power through Cost Savings* (Alexandria, Virginia: Center for Naval Analysis, 2006)27.

[92] Ship's cycles consist of transit, time on station (ToS), short work periods (SWPs) comprising of 2nd line maintenance, docking work periods (DWPs) comprising of 3rd line overhauls, trials periods and finally workups (WUPS).

UV section which leaves how to best maximize SWPs, DWPs and trials. These periods can be minimized by shortening their durations, or lengthening their periodicity.

SWP durations and periodicities stem from the need to address a growing list/backlog of corrective maintenance (CM) issues as well as conduct complex preventative maintenance (PM) routines.[93] CM can be significantly reduced by deliberate and planned PM which requires a robust enterprise resource planning tool (ERP). Permitting highly trained technicians to perform PM rather than routine shipboard task decreases the likelihood of CM occurrences. CM can also be reduced by minimizing sensitive systems' exposure to harsh external elements through modularity. Figure 14 illustrates the I-Mast concept which protects antennae and provides inboard access to processing equipment.

Figure 14- I Mast
Source: Thales Group, "Integrated Mast Family"

[93] CM aims to fix malfunctioning systems. CM can be performed at sea for minor issues (1st Line), or alongside at the Fleet Maintenance Facility (FMF) which is considered 2nd line maintenance. PM aims to prevent known failures from occurring akind to changing the oil or filters in a vehicle. Simple PM can be performed at sea whereas complex routines are conducted alongside in conjunction with FMF. 3rd line maintenance consist of either system or seaframe overhauls where key components are replaced or remediated in order to continue their lifecycle.

A plug & fight architecture can also reduce CM by enabling PM and storage to occur in controlled environments. Lastly, CM can be significantly reduced by minimizing systems with moving parts and maximizing solid-state equipment. Complex PM routines often impact SWP durations. The complexity of these PMs are often caused by access and staging. [94] Modular ship construction that accounts for deliberate access can significantly reduce the duration of complex PM and as a result the length of SWPs.

Similar to SWPs, modular ship construction can enable access for complex overhaul activities performed during DWPs. Figure 15 illustrates the USN's average overhaul duration over 5 years. Surface combatants overhaul duration remained relatively constant at just under 10 months.

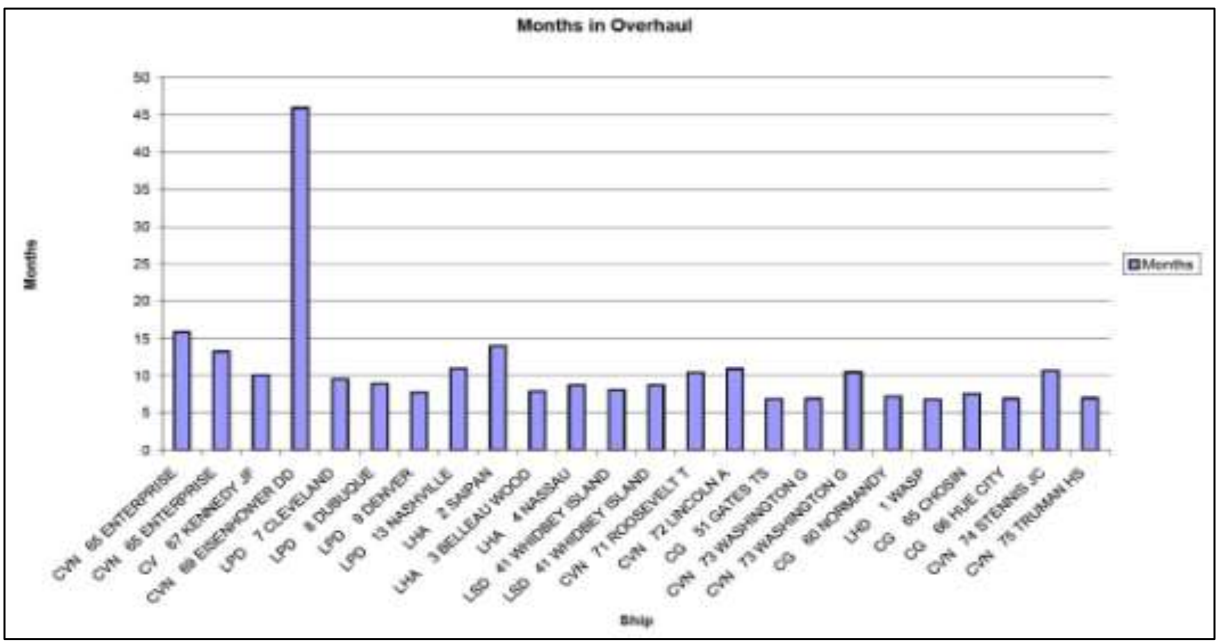


Figure 15- USN overhauls during a 5 year period
Source:Choi,"Improving Navy's Buying Power Through Cost Savings",18.

[94] Top side staging of mast and upper decks often takes more time than the actual maintenance routine. The same issues arise for staging and removal of deck plates for access to machinery spaces.

Efficiencies gained during DWPs are marginal compared to the potential benefits of extending periodicity between DWPs. That said, DWP delays are often due to Government Furnished Equipment (GFE) re-installation periods where synchronization between major system overhauls and seaframe overhauls conflict. Systems are often not ready, or ready too early but poorly stored requiring some rework. Plug & Fight modules decouple mission system overhauls from seaframe overhauls potentially reducing the length of GFE reinstallation periods during DWPs. [95] Anecdotally better shipboard access, reduced CM and increased PM should extend periodicity between DWPs however further studies are required to determine the validity of these concepts. Modularity, robust ERPs, reduced exposure of systems and the advent of solid state are fairly new concepts and little data is available to fully analyse the impact they may have on DWPs.

Reducing trial periods are all about reducing re-trialing. Retrials occur when systems are not fully set-to-work (STW) or performance results are not achieved. Involving OEMs during STWs minimize CM required during trial periods. Furthermore, robust and accountable factory acceptance trials (FATs) are essential to reducing problems occurred during STW. A plug & fight architecture holds the potential of conducting robust STWs in controlled environments. The following analysis utilizes an internal DRDC study to interpret the Canadian validity of this strategy[96]:

1. Completeness: [8] Current and future health monitoring technologies along with efficient system of systems access have been tested and demonstrated. The USN has fully adopted

[95] Mission systems such as the 57mm Main gun are removed during docking working periods and sent to the OEM (Bofors in Sweden) for a complete overhaul. Overhauls of these systems and the seaframe seldom align and cause significant rework in staging of the seaframe or rework on the mission system.
[96] Alex Bourque and Ramzi Mirshak, *Effects of Platform Numbers on the Projected Capacity of the Canadian Surface Combatant Fleet* (Ottawa: DRDC CORA,[2015]).

a condition based maintenance (CBM) approach. In addition, Plug & Fight is maturing and is complimentary to program readjustment;

2. Suitability: [9] CSC ships can be designed to exceed 6 month on station time. [97] CSC ships need only to extend OPCYCLE by 5% in order to yield ROI exceeding shipbuilding inflation[98];
3. Acceptability: [8] Fleet mix studies do not associate any incremental risk to increased tour lengths or OPCYLES. It is assumed that ships on station are performing their given task;
4. Feasibility: [7] Industry has both the capacity and capability to support. RCN has the capacity but not the technical infrastructure in place to implement. DND continues to look at in-service support constructs that may compliment or deter a program re-adjustment initiative; and
5. Uniqueness: [6] The RCN does some CBM but it is not automated. DND's current ERP largely focuses on CM and PM. Both Fleet Mix studies propose an in-depth re-look at modifying maintenance profiles of ships.

The concept scores quite high in the validity analysis [84.4%]. Program re-adjustment is a strategy that can be implemented from within Navy lines and the ROI could feasibility be kept in house. This strategy should be considered a *Critical Strategy* for the RCN.

---

[97] The German Navy designed the F125 to remain on station for two years. The F125 is a contender for CSC. See Muller, *New Frigate Underscores Germany's Shift from Cold War Naval Combat*.

[98] CSC capacity study suggests that lengthening a ship's prescribed OPCYCLE by 5% reduces the number of CSC ships needed by 1-2 platforms. This translates to savings between $1.5B-$4B (dependant on CSC acquisition cost). See Bourque and Mirshak, *Effects of Platform Numbers on the Projected Capacity of the Canadian Surface Combatant Fleet*

FORWARD STAGING

Forward staging involves three initiatives: forward home-porting, partially home-porting, and forward maintenance. The concept aims to reduce cost by saving on time and fuel. Forward home-porting is commonly employed by several allied navies who leverage their overseas colonial or strategic hubs as staging areas for their platforms. The concept can be costly based on crew/family lodging as well as remittance dues to the host nations however cost can be mitigated if home-porting occurs with an ally. Partial home-porting consist of having the seaframe remain forward staged while the crew is sent over for operations. Forward maintenance consists of dedicated maintenance teams or contractors that remain forward deployed to perform second line maintenance at strategically chosen support hubs.

The USN and RN have long utilized forward home-porting and therefore do not require further analysis. Partial home-porting remains irrelevant for most expeditionary navies because their home ports are likely near areas of interest, or they possess overseas territories.[99] The concept can be compelling for navies who do not possess either but again this concept has yet to materialize. Forward homeporting holds the risk of immediate eviction due to a host nation’s changing political climate. Conversely, dedicated forward maintenance is a fairly new concept being explored by the USN. The LCS has successfully trialed a new concept called Expeditionary Maintenance Capability (EMC) which consist of forward staging maintenance kits in two 20ft ISO containers filled with tools and spare parts.[100] EMC will allow operational commanders the ability to perform critical preventative maintenance virtually anywhere that has

[99] Most western allied navies have immediate access to the Mediterranean or gulf regions. Additionally many still possess colonial/post-colonial hubs in Africa and the Caribbean.

[100] Megan Eckstein, "USS Fort Worth Successfully Tested Overseas Maintenance Outside of Singapore Hub," USNI News, http://news.usni.org/2015/04/13/uss-fort-worth-successfully-tested-overseas-maintenance-outside-of-singapore-hub.

basic port facilities. EMC also aims to permit operational commanders the flexibility to plan PM maintenance based on fleet operational requirements rather than fixed-firm maintenance cycles. Ships can stay away longer and are less compelled to return to home port or waive (delay) PM routines increasing the risk of sudden CM.

Certain aspects of forward staging are applicable to the Canadian context. AOPS will have a refuelling and staging port in the high Artic. The following analysis evaluates forward staging within the Canadian context:

1. Completeness: [8] The USN is currently trialing its expeditionary maintenance capability;
2. Suitability: [9] Complements *program re-adjustment* and offers the same suitability score[101];
3. Acceptability: [8] Again, the concept is predicated by *program re-adjustment* and offers the same score;
4. Feasibility: [9] Industry has both the capacity and capability to support this initiative. RCN has performed rest-and maintenance periods (RAMPs) for several years. DND is planning for some limited AOPs infrastructure in the Artic. CJOC is planning on activating operational hubs around the world, most of with or near port facilities; and
5. Uniqueness: [6] RAMPs are part of the RCN's battle rhythm however the USN's proposed EMC is quite unique to the RCN. AOPS holds the potential for expeditionary maintenance in the RCN.

---

[101] CORA capacity study suggests that each month in transit reduces a ship's high readiness (HR) by 1.7% over a 5 year OPCYCLE. Alone the impact is marginal however this may prove challenging if the navy is wishing to leverage savings gained from program re-adjustment. For instance, consider a west coast ship conducting two separate tours to the Gulf of Aden, this equates to four months in direct transit or a 6.8% decrease in availability. Recall the savings in platform required if an OPCYCLE were readjusted by 5%. See Bourque and Mirshak, *Effects of Platform Numbers on the Projected Capacity of the Canadian Surface Combatant Fleet*.

The strategy scores quite high in the validity analysis [88.8%]. In short, this strategy is already in motion with CJOC taking the lead. The question remains, will this strategy simply offer flexibility to the RCN or truly cost-savings that will mitigate shrinking fleets. This strategy should be considered a *Critical Strategy* for the RCN.

FLEXIBLE CREWING

Flexible crewing consists of synchronizing crewing for operations, training and maintenance. The concept aims to maximize a ship's on station and maintenance time while minimizing transit time in the hopes that this translates into mitigating reduced fleet sizes. During its conceptual phase the LCS program looked at a 4/3/1 concept where 4 crews with 3 hulls generated one forward. Table 3 highlights a RAND study analysing cost savings associated with crew rotations.

Table 3 Estimated LCS savings from Crew Rotations

Savings from crew rotation: LCS hulls and costs ($M05)

1 unit of presence			8 units of presence					Aegis ship savings
	Trad	4/3/1		Trad	4/3/1	Savings		
Hulls	6.1	3.8	Hulls	49.0	30.2	18.8		38
Cost per pres	$106	$60	Cost	$848	$480	$368	(100%)	$2,208
Cost no proc	$45	$31	Cost no proc	$360	$248	$112	(30%)	$672
			Cost proc	$488	$232	$256	(70%)	$1,536

Source:Choi,"Improving Navy's Buying Power Through Cost Savings", 28.

Today, the LCS program has refined the concept to a 3/2/1 ratio intending for one ship to deploy for 16 months with crews rotating every four months. Crews not on deployment are either conducting maintenance or training on the alternate vessels. CBO estimates a *25%* increase in platform throughput associated with the 3/2/1 concept which is equivalent to 1.25 ships operated independently. [102] Although crew rotation shows significant budgetary promise for smaller

[102] Budget Office The Congressional, *Options for the Navy's Future Fleet*,[2006]).

crewed vessels, a CRS report cautions against doing so for larger ships. [103] The report suggests recent experiments with more complex ships have not gone well due to the logistical and maintenance challenges associated with large crews. The CRS report also suggest that crews still feel an affinity towards their ship and introducing this new concept will take time. The following analysis seeks to clarify if flexible crewing is pertinent for the RCN:

1. Completeness: [8] The USN is currently adopting its 3/2/1 concept. The RDN also performs crew swaps on a regular basis. The RCN performed a crew swap with HMCS TORONTO in 2013[104];
2. Suitability: [9] As discussed CBO reports a 25% ROI on adopting flexible crewing. That said the RCN would not directly financially benefit in personnel reduction as personnel budgets are centrally managed by the Department. The RCN would benefit from reduced transit times and the flexibility afforded by keeping ships forward;
3. Acceptability: [5] Risk does not increase; it is simply distributed amongst crews therefore solely looking at this strategy in isolations, risk should remain the same as the current fleet;
4. Feasibility: [9] Industry, RCN and DND have successfully completed crew swaps in the past few years; and
5. Uniqueness: [4] Flexible crewing remains adhoc and not enshrined in doctrine. The few instances demonstrated thus far were born out of necessity and may or may not continue to be part of regular RCN business.

---

[103] Ronald O'Rourke, *Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress*Congressional Research Service,[2013]).
[104] Andrew Vaughan, "Navy Low on Frigates to Ship Back HMCS Toronto Crew," Canadian Press, http://www.cbc.ca/news/canada/nova-scotia/navy-low-on-frigates-to-ship-back-hmcs-toronto-crew-1.1392444.

The concept scores moderately well in the validity analysis [77.7%]. The strategy warrants further analysis and in depth study. Once completed, the strategy should be included in RCN doctrine. This strategy should be considered an *Essential Strategy* for the RCN.

The significance of O&M cost throughout the lifecycle of a ship highlights the fact that measures taken to reduce these cost have a meaningful impact on a navy's subsequent purchasing power. Of all the cost-saving categories, *Distributed Sustainment* is predominantly within the Navy's span of control. Ship's maintenance programs, staging and crewing schemes are in large part managed by the navy and consequently any savings accrued by these activities directly play a role in mitigating shrinking fleets. Ship lifecycles are exceedingly long; *Distributed Sustainment* aims to evenly disperse the overwhelming cost of operating a Navy by seeking strategies that incite lean and efficient practices. Unfortunately *Distributed Sustainment* strategies cannot yield their full potential unless certain measures are taken at acquisition. The following chapter will explore strategies necessary at acquisition that galvanize those in *Distributed Sustainment* from reaching their full potential.

CHAPTER 4: DISTRIBUTED ACQUISITION

Recall that 70% of the total cost of ownership is attributed to operations, modernisation and people leaving the remaining 30% for acquisition. [105] Conversely CBO estimates only 50% for acquisition leaving a 20% discrepancy between both estimates.[106] The delta is likely based on the fact that CBO does not succinctly include modernisation where the Janes editorial's broad brush figure does. Regardless of the true lifecycle cost associated with modernization, the fact remains that modernizations are often overlooked and their cost can be quite substantial. Furthermore cost can significantly escalate if modernization is not conceptualized during initial procurement. Much has been written about keeping ship building cost low by adopting commercial industry best practices and sound program management during design and build therefore the emphasis of this section is about reducing lifecycle cost through initiatives that must be conceived at acquisition. [107] Cost savings are gained by dispersing certain acquisition activities that hopefully foster predictability throughout the lifecycle. These activities and initiatives include *Distributed Modular Construction*, *Distributed Margins*, *Distributed Scalable Commonality and Life-Cycle Synchronization*. In doing so, *Distributed Acquisition* aims to mitigate obsolescence on arrival and maximize a seaframe's service life.

DISTRIBUTED MODULAR CONSTRUCTION

Distributed Modular Construction (DMC) comprises two main features. Firstly it describes how a ship is built and assembled. Modules are independently constructed followed by an incremental assembly of the ship based on sequencing and design requirements. Secondly it

[105] "Opinion - LCS: The US Navy's 'Disruptive' Warship."
[106] Douglas Elmendorf, "Life Cycle Cost of various Navy Ships," *Congressional Budget Office* (2010), 2. https://www.cbo.gov/publication/21398.
[107] John F. Schank et al., *Keeping Major Naval Ship Acquisitions on Course: Key Considerations for Managing Australia's Sea 5000 Future Frigate Program* (Santa Monica, CA: Rand, 2014).

describes where modules are built and assembled. In DMC modules can be built at separate yards but transported and assembled at the prime yard. Advantages on *how* DMC is conducted include concurrent activity (and associated time savings), process familiarity and specialization (and associated savings in efficiency) as well as opportunity for redesign prior to assembly (and time associated mitigated delays). Disadvantages include increased program management complexity and potential dissymmetry in workmanship. DMC's advantages associated with co-locating module production at multiple yards are twofold. Firstly, yards are likely in separate political districts which increases the political allure of the build. Sharing the political capital raises the program's political profile which likely creates easier project approval. This on itself is not a cost-savings benefit however delays caused by lack of political endorsement ultimately cost money. Secondly dispersing builds improves capacity and throughput which yields savings on construction time. Disadvantages with employing multiple yards include complex contractual relationships between yards as well as inconsistencies between workload allocations. Stricter quality control between yards adds additional effort to government program teams which potentially adds to project overhead.

DMC is not limited to seaframe hull sections but can also include *topside effectors* like the aforementioned I-Mast or *platform system modules*. Figure 16 illustrates the range of capabilities that can be incorporated in a DMC architecture. As previously mentioned these modules can significantly benefit life-cycle management by providing ease of modernization by decoupling system overhauls from seaframe overhauls.

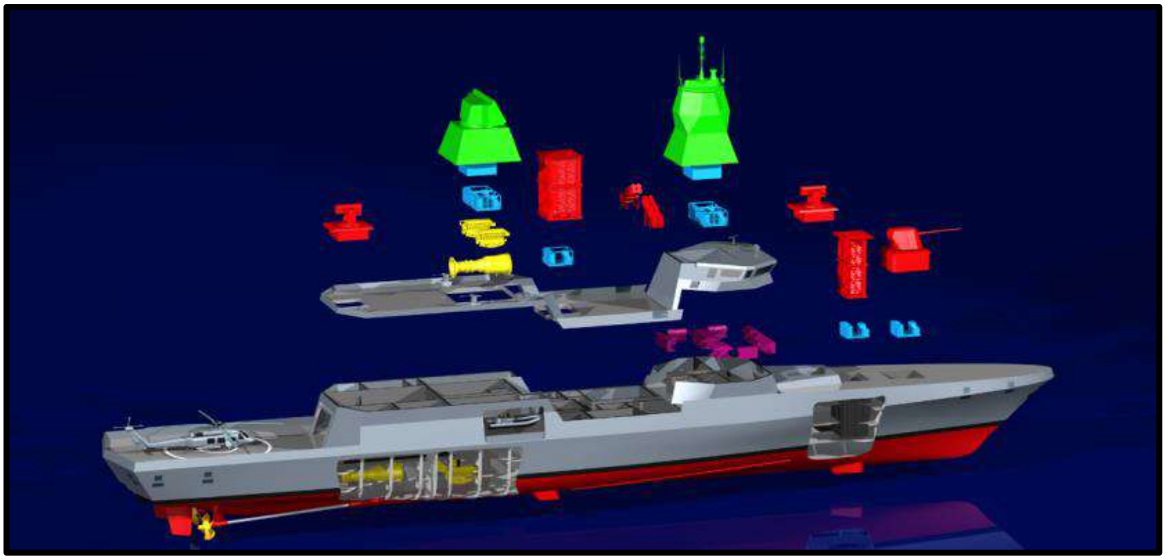


Figure 16- Effector Modularity
Source: ThyssenKrupp Marine Systems, "Addressing the Challenges of Modern Warship Design".

Modular Platform systems enable increased standardization in pipes and fittings providing further cost-savings benefits in commonality. Their common dimensions can also be translated to standardized compartment sizes corresponding across a class or fleet. Figure 17 provides an example of a modular platform system purposely designed for a given ship's modules in mind.

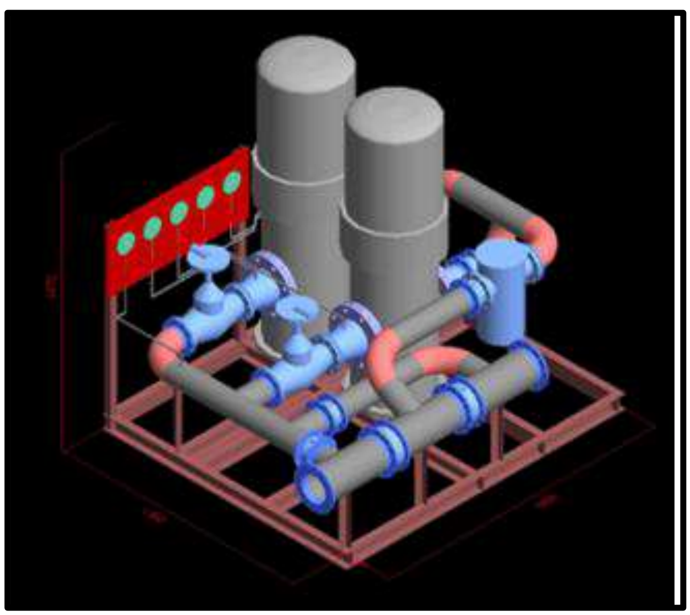


Figure 17-Modular Platform System
Source: ThyssenKrupp Marine Systems, "Addressing the Challenges of Modern Warship Design".

> "We are focusing on the modularisation of the ship to make it easier to build. Production engineering is working with the design team to see how we can maximise the number of pre-outfitted modules built off-site. That strategy means we can realise the benefits of a production-oriented facility in terms of efficiency, safety and quality". [108]

Recall the 10% shipbuilding inflation rate which is directly applied to delays when building a ship. TKMS attest that modular outfitting techniques not only permits simultaneous construction but testing of payload modules which reduces build time and cost. [109] Appendix N provides a comprehensive comparison between recent allied modular construction projects employing multiple yards.

According to RAND change orders add 8% to overall cost of new productions. In addition, change orders also account for 46% of the reasons why projects slip. [110] Figure 18 illustrates the various causes of schedule slippage in shipbuilding.

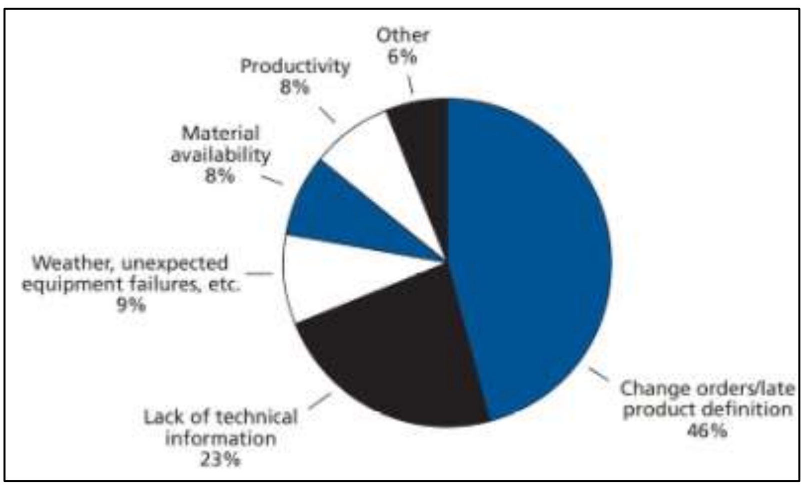


Figure 18- Causes of Schedule Slips Reported by Shipbuilders
Source:Arena, "Monitoring the Progress of Shipbuilding Programmes", 24.

---

[108]Extracted from an interview between The Type 26 Program Manager Geoff Searles and Janes, see: "Modular Warship Concepts: Is 'Plug and Fight' here to Stay?"

[109] Richard Scott, "MEKO Re-Engineered for Mission Modularity," *Jane's Defence Weekly* 43, no. 40 (10/04, 2006).

[110] Mark V. Arena et al., *Monitoring the Progress of Shipbuilding Programmes: How can the Defence Procurement Agency More Accurately Monitor Progress?*RAND, Santa Monica, CA,[2005]).

Modular blocks are often built inside covered work areas mitigating delays due to weather and exposure. Interestingly fewer than 40% of change orders occur during the design phase where they should logically occur but rather disproportionally during assembly and outfitting. Figure 19 highlights the relatively low amount of changes occurring during module block phase of construction.

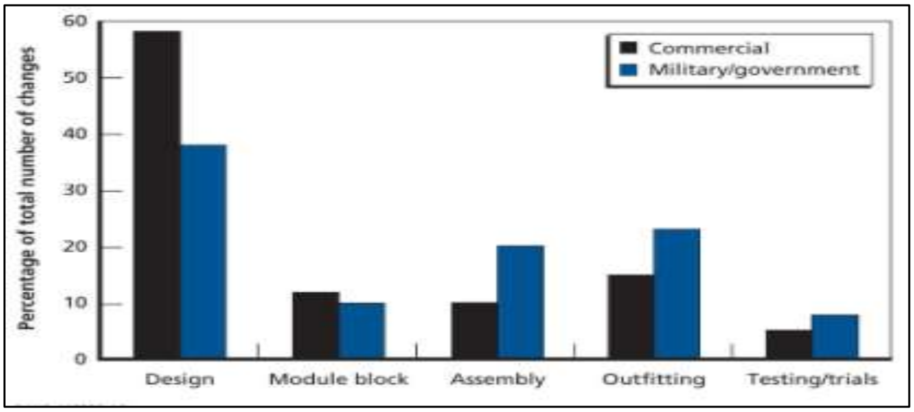


Figure 19-Percentage of Total Number of Changes Occuring at Various Production Phases Source:Arena, "Monitoring the Progress of Shipbuilding Programmes",26.

Increased adoption of DMC could provide a unique opportunity to offset costly change orders during assembly, outfitting and trials if more of these activities are included during module production. ROI again could include savings on time, money and effort. The following analysis will gauge if DMC is applicable to future RCN builds:

1. Completeness: [9] Recall Appendix N, most RCN allies are successfully adopting distributed modular construction;
2. Suitability: [4] ROI is unknown but likely significant during mid-life refits;

3. Acceptability[111]: [9] Recall Appendix N, most allies embark on shared build projects for workload distribution and political capital;
4. Feasibility: [7] Industry and DND are currently building the capability and capacity as part of NSPS[112]; and
5. Uniqueness: [6] AOPS will be built by modular construction from the same yard. CSC truly depends on the procurement strategy the project will adopt. DMC techniques such as modular platforms systems would be relatively new the RCN.

The concept scores moderately well in the validity analysis [77.7%]. Although CSC will be completely built by ISI in Halifax, the strategy warrants further analysis on the impact and potential ROI during a CSC modernization. This strategy should be considered an *Essential Strategy* for the RCN.

DISTRIBUTED MARGINS

Distributed Margins (DM) combines traditional considerations for future hotel service's needs with the standardization brought by platform and mission modules. DM enables future proofing a seaframe without purposefully increasing hotel loads. Therefore DM consists of the inclusion of spaces ready to accept additional hotel capacity rather than actually increasing production margins. Consider DM akind to "fitted-for but not with". Consequently DM reduces cost by permitting the acquisition of lower capacity (cheaper) platform systems.

---

[111] Acceptability in Distributed Acquisition will be based on a different set of critirias since the CORA Fleet Mix are not relevant in determining various stakeholder acceptance. The new measures for acceptability are as follow: a [9] score is achieved if there is a written Government of Canada mandate (policy, legislation), an [8] if it has been proposed by government, [7] if there is a DND policy, [6] initiative proposed by DND, [5] CAF policy, [4] proposed by CAF, [3] RCN policy or doctrine, [2] proposed by RCN (statement of requirements), [1] nil.

[112] Canada. Public Works and Government Services, "National Shipbuilding Procurement Strategy," http://www.tpsgc-pwgsc.gc.ca/app-acq/sam-mps/snacn-nsps-eng.html

Proponents against traditional extra margins stipulate that including excessive margins in order to hedge for future growth causes undue financial cost on acquisition and assumes technology advancement will not create savings in space and hotel services. [113] Case in point includes the advent of solid state computing that has significantly decreased the footprint of combat system components. Increased automation is also dropping crew sizes adding additional space from unused berthing. The argument is more so applicable to revolutionary advances in technology rather than evolutionary advances which often simply require more hotel loads compared to their legacy technologies. Figure 20 supports the argument by illustrating the increased power density requirements of surface combatants over a 30 year period. [114]

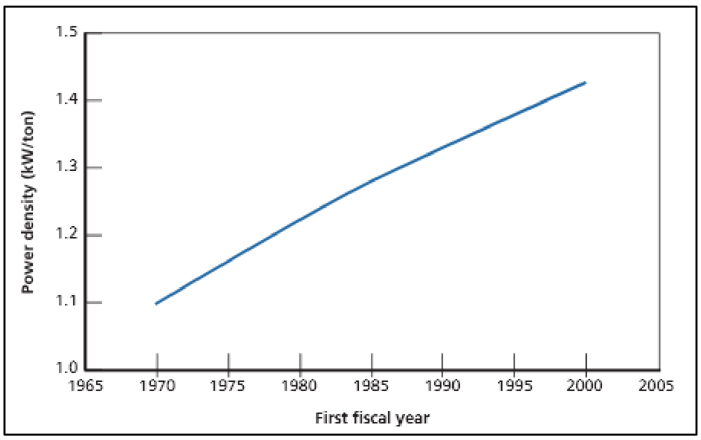


Figure 20- Power Density Trend for Surface Combatants, 1970-2000
Source: Arena, "Why has the Cost of Navy Ships Risen?" 38.

One of the major limitations of arbitrarily adding margins is that it is difficult to predict the weight and optimal location of new combat systems. For instance no one really knows the final weight of rail guns and laser systems. These systems could impact ship's stability and center of

[113] Ronald O'Rourke, *Navy DDG-51 and DDG-1000 Destroyer Programs: Background and Issues for Congress* (Washington, D.C.: Congressional Research Service, Library of Congress, 2014a).
[114] Typical average life-cycle of a surface ship (excluding RCN)

gravity. Appendix O compares DDG-51 Flight III margin growth to DDG Flight IIA. The Appendix highlights the unpredictability of margin forecasting. Some hotel services have increased demands whereas others have lower demands. Fortunately commonality incorporated in DM provides designers the flexibility to strategically place additional supporting platform systems in order to favour ship stability. Of note, DDG-51 is reaching the limits of its margin and further growth could be at risk.

Although margin forecasting remains unpredictable, RAND still suggest that the slight additional cost associated with increased margin inclusions provides significant cost-savings for the lifecycle of the class. Table 4 compares procurement, R&D and acquisition of DDG-51 to a notional flexible platform. The analysis suggest the 3% increase in acquisition cost associated with the flexible platform yields a 32.3% cost savings over the life of the class with similar figures for procurement and R&D.

Procurement Cost Comparisons ($FY10, millions)

	Inflexible Platform (DDG 51)			Flexible Platform (SCAMP)		
	Lead	Average	Class	Lead	Average	Class
Procurement	1,700	1,260	92,280	1,380	850	62,500
R&D	1,130	50	4,550	1,530	20	3,070
Acquisition	2,830	1,310	96,830	2,910	870	65,570

Table 4 Margin Comparison between DDG-51 and Flexible Ship
Source: Schank et al., "Keeping Major Naval Ship Acquisitions on Course",113.

DM holds promise as a cost-savings strategy but should be tempered by the unpredictability of revolutionary advances in technology as well as future threats. Again DM cannot be incorporated in isolation but rather is a complementary strategy to the other initiatives associated within *Distributed Acquisition*. The following analysis evaluates if DM holds the potential for adoption in future RCN builds:

1. Completeness: [9] The concept is widely adopted in most current and future allied builds. The strategy is considered to be very mature;
2. Suitability: [9] Table 4 suggest that a flexible ship would yield a 32% ROI through life compared to an inflexible ship such as DDG-51;
3. Acceptability: [2] There are currently no policies in place mandating distributed margins. The highest level of acceptability would likely be proposed by RCN leadership
4. Feasibility: [9] Builders such as TKMS have proven designs. Additionally, the CPF was designed and built with some measures of margins (power generation); and
5. Uniqueness: [8] Distributed margins is currently being discussed at the strategic level however it has yet to be operationalised in the RCN.

The concept scores quite high in the validity analysis [82.2%]. This strategy is at risk of being set aside due to the 3% premium during acquisition. For CSC, 3% translates to roughly $1B, or potentially one General Purpose Frigate[115]. Conversely, ROI through life could be as high as $8.5B, money that could be allocated towards a robust and efficient midlife modernization or a continual build program in line with the spirit of NSPS. This strategy should be considered a *Critical Strategy* for the RCN.

SCALABLE COMMONALITY

Scalable Commonality (SC) leverages the unique construction characteristic of DMC and DM to ease seaframe modernization. Full modules can be exchanged in order to modernize ships built later in the program or back fit the earlier ones in order to ensure relevance through life. SC enables evolutionary modernization rather than traditionally costly modernization projects that

[115] Based on the overall CSC project cost outlined in Appendix F.

only provide relevance for a specific portion of the class in a finite moment in time. Common modules also enable scalability which can permits commonality not only by class but fleet wide as well. Common modules can be added or omitted in order to modify ship classes in accordance with evolving future requirements or threats. SC future proofs classes and fleets. SC requires ships to be designed with common modules, namely hotel services. Fortunately common platform systems favour adopting block buy contracts which provide supplier confidence and potential cost savings.

> The concept is that, through more rapid technology refresh pier-side, we can get the full service life out of the ship and it is combat effective for the full service life,[An idea] floating around right now [is to have the] shipbuilders deliver the combat information centre as [an empty] space and we, the navy, will go outfit it with the latest combat system post-delivery. [116]

The USN and TKMS are pioneering SC with their LCS and MEKO FLEX concepts. Appendix P highlights the scalable range of SC. Engine rooms, berthing, and topside effectors are all scalable. Note how the concept also includes spaces allocated for plug & fight mission modules. SC is still in its infancy but given the international success of the MEKO family the concept may see wide adoption in short order. The following analysis investigates if the RCN is ready to adopt such a bold concept:

1. Completeness: [7] The MEKO Flex concept suggests that the strategy is ready for demonstration in an operational environment. The auto industry has fully embraced and operationalized the concept[117];

[116] Fein, *USN Official Says Surface Ship Designs must be More Flexible to Maximise Service Life*
[117] Volvo and VW are currently in production of their versions of scalable commonality duly named Scalable Product Architecture (SPA) and Modular Langsbaukasten (MLB) respectively.

2. Suitability: [5] VW suggests that MLB will cut production time by 30%.[118] They consider the concept as their strategic weapon however this may not be directly transferable to the maritime industry;
3. Acceptability: [8] NSPS has proposed commonality for some time. [119] In addition, CSC intends on designing and building two ship variants with one common hull[120];
4. Feasibility: [2] TKMS's MEKO Flex suggests that industry has the capability but not the capacity. DND and the RCN currently do not have capacity or capability to conduct scalable commonality; and
5. Uniqueness: [6] Element of scalable commonality can be found throughout CSC's SOR.

The concept scores quite low in the validity analysis [62%]. Commonality at large is a widely accepted necessity in future shipbuilding and no additional attention for RCN is required. This strategy should be considered a *Routine Strategy* for the RCN.

LIFE-CYCLE SYNCHRONIZATION

Life-Cycle Synchronization is analogous to Program re-adjustment discussed in *Distributed Sustainment* where through life management of the platform is planned. Life-Cycle Synchronization differs with the latter in that through life phasing and synchronization is considered at acquisition. Furthermore Life-Cycle Synchronization takes a pan fleet view in order to leverage DMC, DM and SC's unique attributes. Program re-adjustment is more so operational planning of classes whereas Life-Cycle Synchronization leans towards strategic

---

[118] Laurence Frost, Andreas Cremer and Paul Lienert, "Insight: Has Volkswagen Discovered the Holy Grail of Carmakers?" Reuters, http://www.reuters.com/article/2013/02/11/us-autos-volkswagen-future-idUSBRE91A04D20130211.
[119] Canada. Public Works and Government Services, *National Shipbuilding Procurement Strategy*.
[120] Canada. Department of National Defence, *Statement of Requirements: Canadian Surface Combatant Draft*.

planning of the fleet. Life-Cycle Synchronization takes an integrative and symbiotic approach to life-cycle management of all the platforms in the fleet.

The USN has starting employing elements of Life-Cycle Synchronization-like strategies out of necessity. In 2006 DDG-103 suffered a major electrical fire while under construction at NGSB-GC in Pascagoula, Mississippi. Bath Iron Works (BIW) already had in production several compatible modules destined for DDG-108 and DDG-106. These modules where combined and sent to NGSB-GC in order to keep construction of DDG-103 on track. Figure 21 illustrates a side view of the multi-sourced deckhouse arrangement of DDG-103.

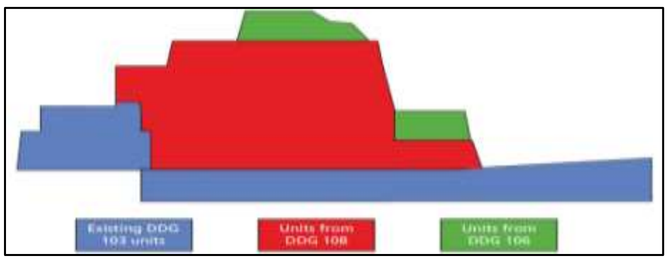


Figure 21- DDG-103 Composite module Deckhouse
Source: Smallman et al.,"Shared Modular Construction of Warships",34.

The example does not explain Life-Cycle Synchronization but rather highlights its potential. Planners are leveraging distributed acquisition in order to keep their naval enterprise synchronized. The example is not just limited to the synchronized construction of three platforms but involves enterprise wide resource planning. If DMC, DM and SC are truly leveraged, Life-Cycle Synchronization encompasses the phasing and sequencing of evolutionary capability management. Life-Cycle Synchronization is relatively conceptual and requires mature distributed sustainment and acquisition frameworks already in place. Consider Life-Cycle Synchronization as a visionary cost-savings strategy. The following evaluates the strategy in the Canadian context:

1. Completeness: [7] The concept has been simulated by various ERPs and is ready for the operational environment;
2. Suitability: [9] Like Program re-adjustment, Table 4 suggest that a flexible ship (designed taking distributed margins in mind) would yield a 32% ROI through the life of the ship compared to an inflexible ship such as DDG-51;
3. Acceptability: [6] There are currently no policies in place mandating life-cycle synchronization. That said, DND aims to introduce in-service support (ISS) contracts for AOPS, JSS and potentially CSC. ISS hold the potential of greater Life-Cycle Synchronization but truly depend on the final design of these ships as well as the details within the ISS contracts;
4. Feasibility: [4] Industries such as the auto industry have demonstrated the propensity to plan mid-life refreshes at the design phase. The shipbuilding industry seems to be gravitating towards the concept as well. The RCN and DND have a robust ERP that can be tailored to include life-cycle synchronization; and
5. Uniqueness: [8] Currently being discussed at the strategic level but has yet to be put into doctrine or operationalized.

The concept scores moderately well in the validity analysis [75.5%]. Ongoing initiative to connect DND ERPs with Industry ERPs may highlight the need for greater life-cycle synchronization. ROIs in the auto industry hold promise and should not be discounted. This strategy should be considered an *Essential Strategy* for the RCN.

> Future Surface Combatant is where OPNAV [Operational Navy staff] is specifying the five design features [de-coupled payloads, standard interfaces, rapid reconfiguration, preplanned access routes, and sufficient growth margin for

> distributed systems] for flexible ships. That is the first time [we are] seeing all five of these together, FSC is nirvana for flexible ships design. [121]

Distributed Acquisition closes the loop on the cost-saving potentials associated with distributed sustainment. Although acquisition cost notionally only amounts to 30% of lifecycle cost, the fact remains the steps and measures taken during acquisition have a direct impact towards sustainment, modernization and operations. Taking into consideration flexible design and construction modalities opens the door for enterprise wide synchronization through the life of a fleet.

---

[121] The USN has recently setup a specific office that deals with merging Distributed sustainment and acquisition type ideas into their future combatants. See: Fein, *USN Official Says Surface Ship Designs must be More Flexible to Maximise Service Life*.

CHAPTER 5: COA DEVELOPMENT

The following chapter will group and phase each cost-saving strategy based on the urgency evaluated during the RCN validity analysis. The overall intent is to extract commonly themed strategies in order to develop Lines of Operations (LOOs). Table 5 illustrates the results of the validity process.

Critical Strategy	Essential Strategy	Routine Strategy
Plug & Fight Modularity	Squadron Capability Sharing	Quantity as a Quality
UVs	Evolved Interoperability	High Low Mix
NCW	Flexible Crewing	Scalable Commonality
NGFS	Life-Cycle Synchronization	
Program Re-adjustment	Distributed Modular Construction	
Forward Staging	Smart Kill	
Distributed Margins		

Table 5 Validity Process Results

PHASING

The validity process pointed out that certain circumstances will not allow the RCN to pursuit all strategies right away regardless of how enticing a given cost-saving strategy could be. Applicable strategies must be phased since some are based on technologies, tactics or procedures developed by their contemporaries. RCN relevant cost-saving strategies can be categorized into three major phases based on actions required by RCN leadership. The *Shape* phase necessitates RCN leadership to *influence* specific requirements in RCN new ship builds. The *Create* phase involves RCN leadership creating projects that develop capabilities which would materialize into cost saving strategies. The *Evolve* phase is centered on leadership transforming doctrine in order to operationalize and grow those cost-saving strategies to their full potential. Cost-saving strategies are later sequenced in their phase based on necessity (urgency + ROI).

GROUPING

Applicable RCN costs saving strategies are further grouped into common themes in order to build sequentially logical LOOs. In doing so, strategies identified as routine were not included. The analysis deduced 3 main LOOs: *Get Modular, Get Connected, and Get Synchronized.*[122] Table 6 summarizes the results. Each strategy indicates its ROI if known.

Pre-Condition	Get Modular	Get Connected	Get Synchronized
Distributed Modular Construction [unk]	*Plug & Fight Modularity [38%]*[123]	*NCW [36.4%]*[124]	*Program Re-adjustment [unk]*
Distributed Margins [32%][125]	*UVs [unk]*	*NGFS [unk]*	*Forward Staging [unk]*
	Squadron Capability Sharing [unk]	Evolved Interoperability [unk]	Life-Cycle Synchronization [unk]
	Smart Kill [unk]		Flexible Crewing [38%][126]

Table 6 RCN Cost-Saving Strategy Lines of Operations

[122] These LOOs are similar to themes embraces by the USN submarine community Work, *Naval Transformation and the Littoral Combat Ship*, 125.
[123] See footnote 35.
[124] Discussed in NCW section during validity analysis. Rough order of magnitude extracted by comparing number of non NCW ships that could be afforded vice the amount in a NCW architecture in accordance with $26B budget presented in CSC Options Analysis brief .
[125] See Table 4.
[126] See footnote 67.

OP DESIGN

Figure 22 illustrates the proposed OP Design generated from grouping, phasing and sequencing all critical and essential cost-saving strategies applicable to the RCN. Of particular note *Budget Ceiling* was determined to be the Center of Gravity (CoG). Budget ceilings can work either way for this Op Design. A near limitless budget (wartime) may dissuade the need to mitigate shrinking fleets. Meanwhile a shrinking budget may impact initial investments required to kick start some of these strategies. Recall that mitigating shrinking fleets is the genesis of this paper and as a result the aspirational end state.

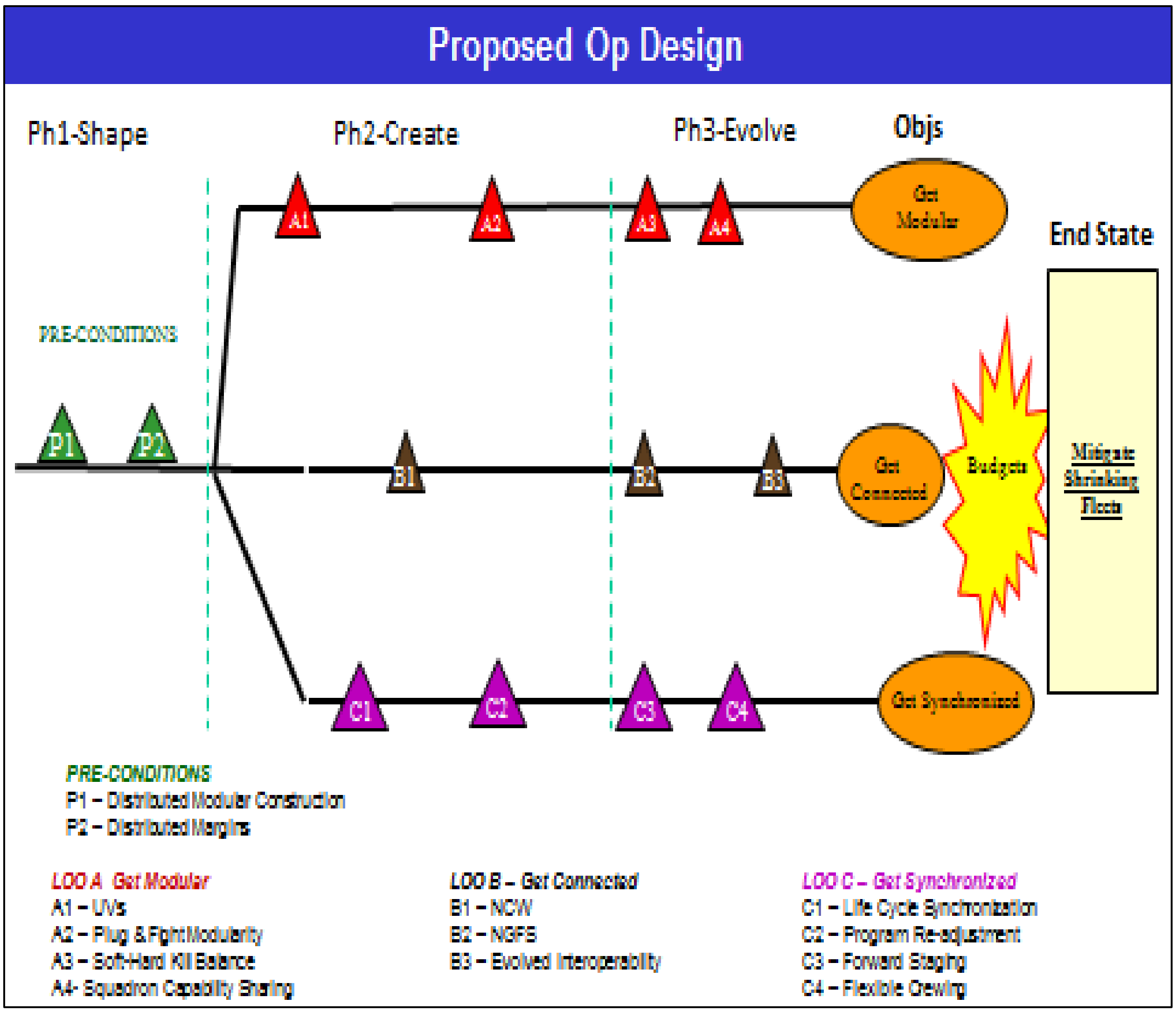


Figure 22 Proposed Op Design

CHAPTER 6: IMPACT ANALYSIS

Known ROIs for each cost-saving strategy were aggregated by LOOs as discussed in Table 6 and applied to each class numbers proposed by CFDS in order to determine the impact on platform numbers. Note, not all cost-saving strategy can be applied to all classes in CFDS. For instance Plug & Fight cannot be applied to JSS since the design is finalized. Table 7 illustrates the results of the analysis and Appendix R rationalizes why certain platform bonuses where applied to certain classes of ships.

	MH	AOPS	MCDV	SSK	JSS	C2AD	GP
CFDS	**15**	**8**	**12**	**4**	**3**	**3**	**12**
Pre-Conditions (+32%)	0	2.56	0	0	0.96	0.96	3.84
LOO1 (+38%)	5.7	3.04	0	0	0	1.14	4.56
LOO2 (+36.4%)	0	3.36	0	0	0	1.26	5.04
LOO3 (+25%)	3.75	2	3	1	0.75	0.75	3

Table 7 Virtual Platform Bonus Generated by RCN Cost-Savings Strategies[127]

The sum of all aggregates generated a *Virtual Fleet* composed of CFDS proposed platforms as a baseline and the platforms (bonuses) gained from cost-savings strategies. Figure 22 delineates the outcome that each LOO contributed to the overall *Virtual Fleet*.

[127] Figures in table indicate virtual platform bonus per class. For instance LOO3 adds 25% more platforms to the 12 ship MCVD class which is equivalent to 3 additional ships.

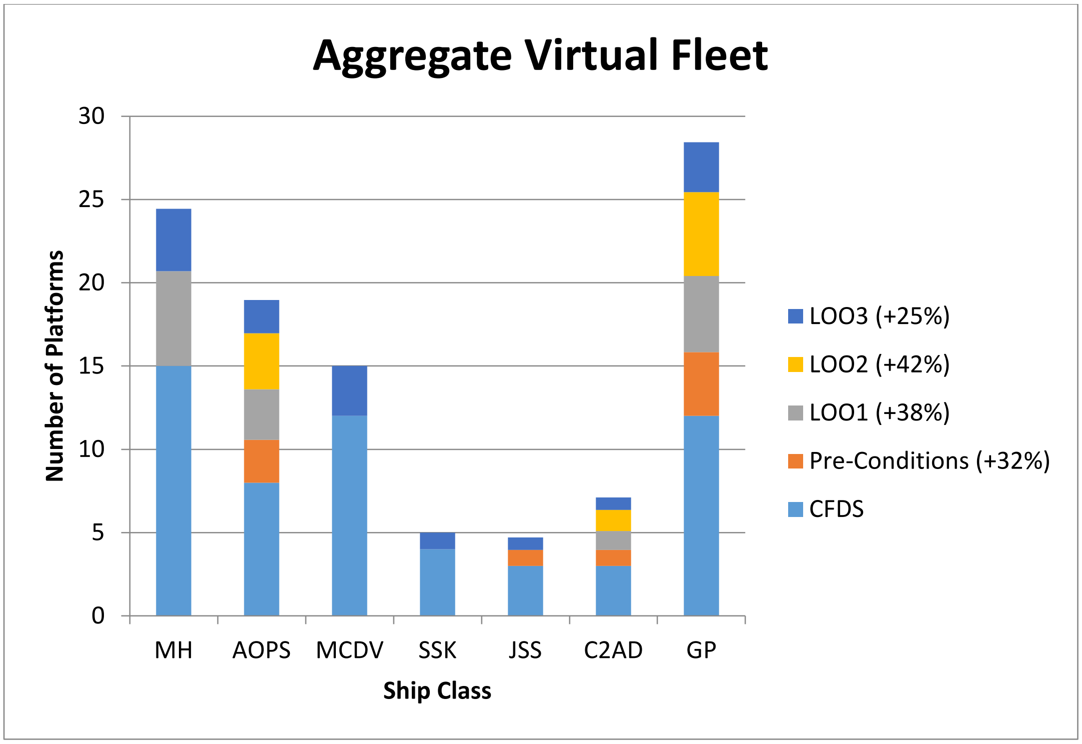


Figure 23 Aggregate Virtual Fleet

Note how LOO3 is applicable across all classes in both current and future builds. *Get Synchronized* should be of primary concern for the RCN. Also, AOPS is surprisingly receptive to cost-saving strategies. Although the class is only intended for constabulary purposes, pan fleet application of cost-saving strategies may have a spillover effect on this class making it a potentially formidable platform.

Figure 23 compares the Aggregate Virtual Fleet to the aspirational CFDS fleet. The analysis highlights the need to produce or select designs that are flexible as the ROI can be significant. Note that not all cost-saving bonuses were applied since many were unknown.

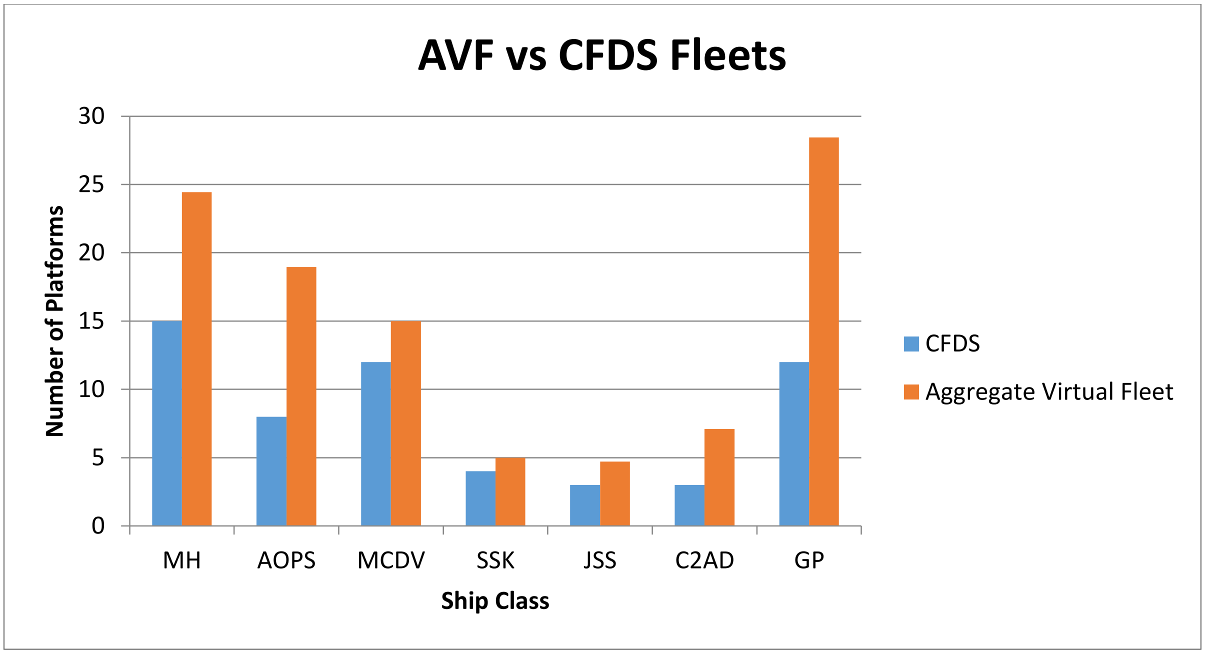


Figure 24 AVF vs CFDS Fleets

The net result is a potential 50% increase in platforms, most of which are applied to the new builds. [128] In contrast recall the 40% average decline in allied platforms since the end of the Cold War. [129] These figures are close enough to warrant future consideration and study. If anything these figures emphasise the importance of adopting cost as a strategy because in naval warfare, numbers do count. [130]

---

[128] Excluding maritime helicopters CFDS accounts for 42 platforms and the aggregate virtual fleet accounts for 84.62 (85) platforms.
[129] McGrath, *NATO at Sea: Trends in Allied Naval Power*.
[130] Hughes, *Fleet Tactics and Coastal Combat*, 378.

CHAPTER 7: RECOMMANDATIONS

The intent of the Op Design is not to mandate what the RCN should do but rather how the RCN should proceed if cost is adopted as a strategy. The evaluation generated in the Impact Analysis admittedly required more scientific rigour in order to truly access the Canadian feasibility of allied cost-saving strategies. That said, three main recommendations became evident:

1) Further detailed studies are necessary in order to determine Canadian specific ROIs in order to steer future designs[131];
2) Cost must be adopted as a strategy. We need to fully flush out our entire naval enterprise from end to end. We need to establish the indirect links between strategy and budgets. Budget remains our CoG and we need to know where to apply our energy; and
3) We need to establish a force generation process for developing strategy. Strategic talent cannot grow overnight. The RCN needs to grow its institutional strategic depth. Strategic professionals should be fostered and mentored in order for the institution to keep growing.

[131] Studies should include: *Smart Kill* options analysis based on RCN armament disposition and threat analysis; *Expeditionary Maintenance Capability* feasibility study; *Distributed Margin* impact analysis; and, *Program re-adjustment/Life-Cycle Synchronization* parametric study.

CONCLUSIONS

Western navy fleets continue to shrink despite steadily increasing defence spending from the rest of the world. Figure 24 illustrates increased defence spending everywhere except for Europe and North America.

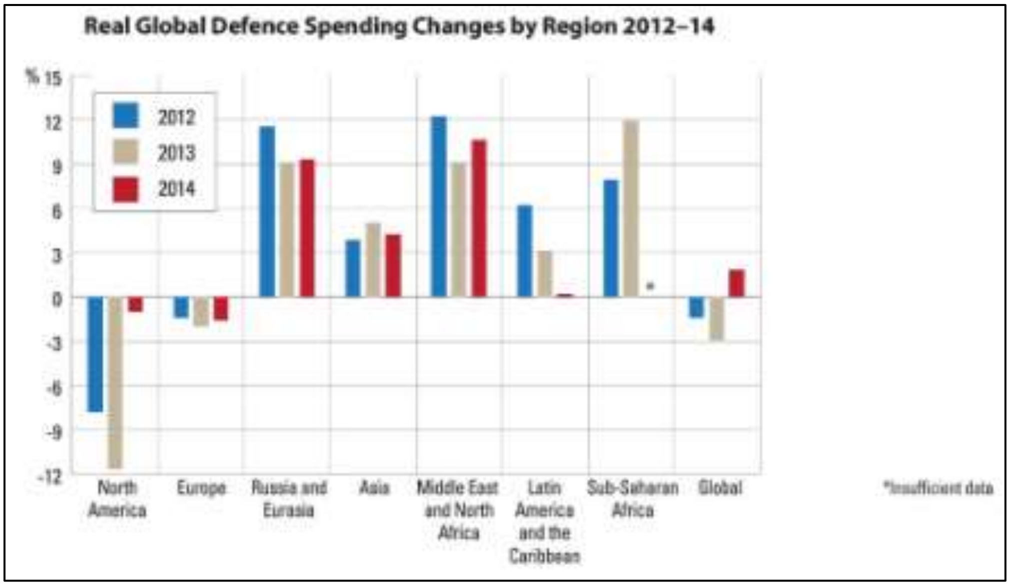


Figure 25 Real Global Defence Spending Changes by Region 2012-14
Source: IISS, The Military Balance 2015, 22.

The factors contributing to shrinking fleets are not new. Modern navies have historically attempted to keep a pace with peer navies by building the most sophisticated high-tech ships they could afford often overlooking revolutionary changes in technology, tactics and operations. [132] Before the First World War, submarines were inexpensive in comparison to Super Dreadnaughts. [133] Today submarines hold the title for the most sophisticated platform in a fleet yet navies have sharply reduced their submarine fleet sizes in an attempt to maintain their competitive edge. Appendix S highlights the sharp reduction in worldwide submarine fleets (with exception of

[132] Nicholas A. Lambert, *The Submarine Service, 1900-1918*, Vol. ol. 142 (Aldershot, Hants, England ; Burlington, Vt.: Published by Ashgate for the Navy Records Society, 2001), xxvii.
[133] Super Dreadnaughts were considered the most sophisticated platforms at the time.

China) reinforcing the fact that cost drivers have and continue to be technology driven. Tomorrow, unmanned vehicles may repeat the same pattern submarines applied to Super Dreadnaughts in 1914.

If costs are rising and western defence budgets are decreasing then one-for-one replacements of ships are unaffordable and unachievable. Western navies must decide if they wish to live with fewer ships or devise innovative ways to mitigate loss of platforms.

The aim of this paper was indeed to find ways that mitigate against lack of numbers. Unfortunately numbers do count in naval warfare and therefore the attention of this paper had to probe beyond changes in operational employment.[134] Acquisition and sustainment practices need to be considered along with a long term strategic view on revolutionary technological innovations. Appendix M emphasises the fact that increased acquisition budgets do not correlate with increased life-cycle cost. How a class is designed in relation to how it is envisioned to be employed is more pertinent then the initial price tag. Cost is not synonymous to money; cost is closer linked to effort. Effort in turn is the product of resources and time producing an outcome. Fortunately effort can be distributed.

At the heart these cost-saving strategies primarily aim to distribute effort throughout the entirety of the naval enterprises. Alone most of these cost-savings strategies yield mild to moderate savings but their aggregate holds the potential to stem the trend towards shrinking fleets. For example, squadron capability sharing alone permits lower acquisition cost but restricts flexibility in operations making this strategy undesirable. Combining plug & fight modularity with squadron capability sharing provides flexibility in operations while lowering

[134] Hughes, *Fleet Tactics and Coastal Combat*, 147.

overall seaframe and combat systems life cycle cost. Some cost-saving strategies simply can't operate on their own. For instance scalable commonality depends on distributed modular construction's unique build techniques and features.

The key take away from this paper is the importance in the interaction between cost-saving strategies. Throughout the paper linkages between strategies were made and unintended interdependencies were discovered suggesting that lines-of-operations are more important than individual cost-saving strategy. Their interdependencies also suggest that cost needs to be the lens of which strategy is filtered. Cost-saving strategies found in distributed acquisition and sustainment would naturally originate from engineering and logistics communities. Likewise cost saving strategies found in distributed force and effects would probably be proposed by the operational communities. Unfortunately this does not work. The unapparent synergies between cost-saving strategies are too strong to be developed and adopted independently. Situational awareness at all levels of naval activity needs to become the highest priority. Cost-saving strategies need to be grouped, synchronized and phased appropriately in order to remain feasible.

A secondary conclusion to this paper is the need for more Canadian specific studies in cost-saving strategies. Shipbuilding for one class is expensive and takes time. Fleet recapitalization and sustainment is even harder. Naval enterprise wide studies are essential to getting it right. Fleet mix studies are an important first step but a wholesome understanding on the impact of sustainment and effects are necessary. For instance in Canada a great deal of importance is placed on tactical development and employment of hard kill. Smart kill emphasises the operational and strategic development and employment of right cost weaponeering.[135]

[135] CSBA proposes a whole new approach to Anti-Air and Anti-Submarine battle with a cost-effective employment of munitions. See Clark, *Commanding the Seas: A Plan to Reinvigorate US Navy Surface Warfare*

Similarly much attention is placed on platform capability trade-offs at acquisition in order to lower procurement cost yet little considerations are made for measures that can substantially lower life-cycle cost.[136] A striking requirement for the RCN is the need to operationalize strategies of all nature in order to recapitalize the fleet. Fortunately NSPS provides a platform that binds requirements, industry and politics. Navies aspire for a cutting edge fleet, industry hopes for stability and the Government is compelled to reduce cost. All parties are motivated by the survival of their brand. Survival is risky, but recall, risk can be distributed.

> *It is not the strongest or the most intelligent who will survive but those who can best manage change.*
>
> -Leon C. Megginson

[136] Canada. Department of National Defence, PMO CSC, *Options Analysis Brief to CMS*

APPENDIX A- COST SAVING STRATEGY SCORING MATRIX

Score	Completeness (TRL[137])	Suitability[138]	Acceptability[139]	Feasibility[140]	Uniqueness
9	Proven Operationally	30%	≥100% below risk threshold	I+D+N= Cap and C	No such strategy exist in CAF
8	Tested and Demonstrated	25%	75% below risk threshold	I+D+N= Cap	Proposed at the strat level
7	Strategy ready for demonstration in Operational Environment	20%	50% below risk threshold	I+D+N= C	Developed at strat level (in doctrine)
6	Strategy or susbsystem demonstrated in simulation	15%	25% below risk threshold	2 stakeholders = Cap + C	Op Dev
5	Component validated in simulation	On par with 10% shipbuilding inflation	Meets Risk thresholds	2 stakeholder= Cap	Op Anal
4	Component validate conceptually	8%	25% above risk threshold	2 Stakeholder= C	Op Eval
3	Analytical and experimental critical function proof of concept	6%	50% above risk threshold	1 stakeholder = Cap + C	Tac Dev
2	Technology concept and/or application formulated	4%	75% above risk threshold	1 stakeholder = Cap	IOC Tactical Lvl
1	Basic principles of concepts observed and reported	≤2%	≥100% above risk threashold	1 Stakeholder = C	FOC Tactical Lvl

137 Canada. Public Works and Government Services, "Technology Readiness Level," https://buyandsell.gc.ca/initiatives-and-programs/build-in-canada-innovation-program-bcip/program-specifics/technology-readiness-levels

138 ROI compared against shipbuilding inflation where a 10% ROI would mitigate any loss caused by shipbuilding inflation, therefore a [5] score would be considered a passing markl.

139 Bourque and Eisler, *Fleet Mix Study Iteration II: Making the Case for the Capacity of the "Navy After Next"*, 96

140 Acronyms are as follow: Industry (I), Department of National Defence (D), RCN (N) are the 3 stakeholders, Capability (Cap) and Capacity (C) are the attributes that the stakeholders must possess in terms of resources (people and money).

APPENDIX B- SCALE FOR MEASURING POLITICAL IMPACT

Table 8 Scale for Measuring Political Impact

Description	Political Perspective	Consequence Score
Severe	Loss of Canadian territory or sovereignty. Significant military losses during a Coalition Operation.	75
Critical	Requires military assistance from another country to resolve an issue to Canada's satisfaction (Both Domestic and International). Creates lasting International embarrassment.	30
Significant	Required capabilities (clearly within the responsibilities of the CF) are not immediately available to address a Sovereignty issue or International interest issue. Generates long-term but sporadic interest on the International stage.	10
Measurable	Required capabilities are available but encounter problems during use, reducing effectiveness. Of passing interest Domestically and Internationally.	4.5
Minor	No political interest e.g. scheduling problem results in HMCS HALIFAX missing a collective training opportunity.	1.5

Source: Allen, Fleet Mix Study, 25.

APPENDIX C- STRATEGIC THREAT RISK INTEXT

THREATS	WEIGHT
CONVENTIONAL ATTACK ON CANADA	0.046
TERRORISM AGAINST CDN FORCES	0.007
TERRORISM AGAINST CDN URBAN CENTRE(S)	0.007
SOVEREIGNTY INCURSION	0.006
GENERAL NUCLEAR WAR	0.046
TERRORISM WITH CB WPNS	0.007
LIMITED NUCLEAR WAR	0.046
PROLIFERATION OF WPNS OF MASS DESTRUCTION	0.047
INTERNATIONAL CRIME	0.041
MORE BELLICOSE NORTH KOREA	0.043
RUSSIAN POLITICAL COLLAPSE	0.088
INDIA/PAKISTAN NUCLEAR WAR	0.047
CHINA THREATENS TAIWAN	0.043
MIDEAST INSTABILITY/WAR	0.047
INTERNATIONAL DRUG TRAFFIC	0.041
ENVIRONMENTAL CATASTROPHE	0.043
INCREASED TRADE PROTECTIONISM	0.032
COLLAPSE OF WTO REGIME	0.035
DRAMATIC DEVALUATION OF CDN DOLLAR	0.035
GLOBAL RECESSION	0.062
US ECONOMIC SLOWDOWN	0.032
INCREASED REFUGEE INFLUX	0.047
AIDS EPIDEMIC DEVELOPING WORLD	0.050
RECURRENT GENOCIDES	0.055
WIDENING NORTH/SOUTH GAP	0.050

THREATS	INDEX VALUE
RUSSIAN POLITICAL COLLAPSE	14.1
GLOBAL RECESSION	9.9
RECURRENT GENOCIDES	8.8
WIDENING NORTH/SOUTH GAP	8.0
AIDS EPIDEMIC DEVELOPING WORLD	8.0
PROLIFERATION OF WPNS OF MASS DESTRUCTION	7.6
MIDEAST INSTABILITY/WAR	7.6
INDIA/PAKISTAN NUCLEAR WAR	7.6
INCREASED REFUGEE INFLUX	7.6
GENERAL NUCLEAR WAR	7.3
CONVENTIONAL ATTACK ON CANADA	7.3
LIMITED NUCLEAR WAR	7.3
ENVIRONMENTAL CATASTROPHE	6.9
MORE BELLICOSE NORTH KOREA	6.9
CHINA THREATENS TAIWAN	6.9
INTERNATIONAL CRIME	6.5
INTERNATIONAL DRUG TRAFFIC	6.5
DRAMATIC DEVALUATION CDN DOLLAR	5.6
COLLAPSE OF WTO REGIME	5.6
US ECONOMIC SLOWDOWN	5.1
INCREASED TRADE PROTECTIONISM	5.1
TERRORISM AGAINST CDN URBAN CENTRE(S)	1.2
TERRORISM AGAINST CDN FORCES	1.2
TERRORISM WITH CB WPNS	1.2
SOVEREIGNTY INCURSION	1.0

Figure 26 Military Strategic Risk Index
Source: Finan,Illustrative Canadian Strategic Risk Assessment, 33.

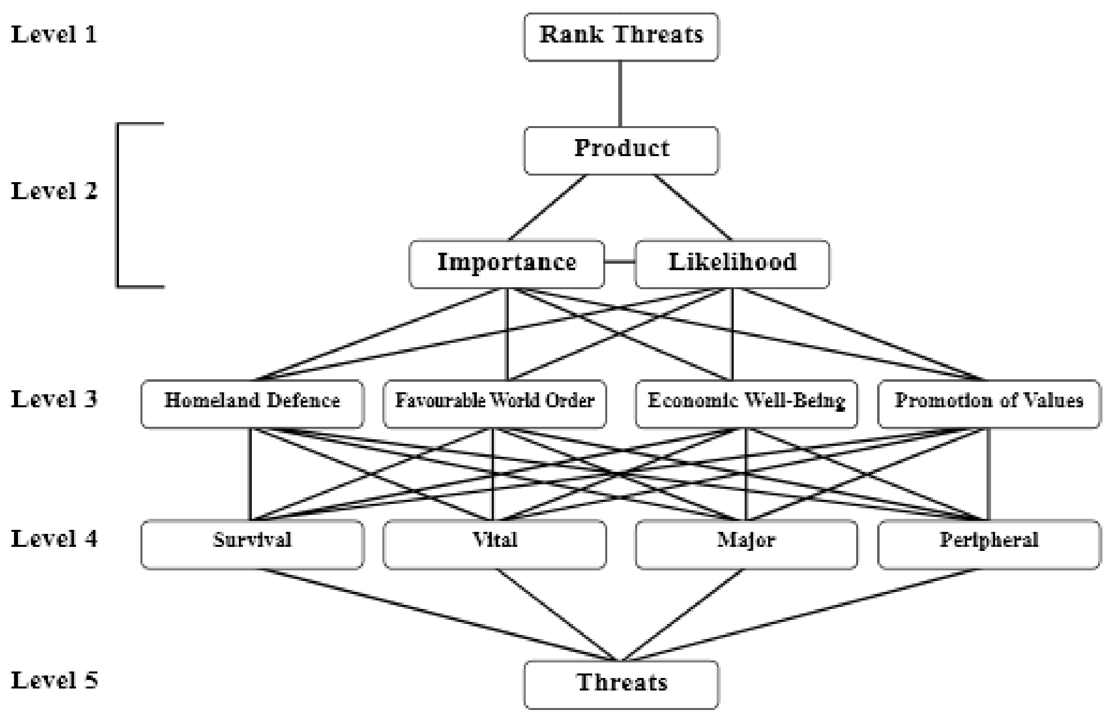
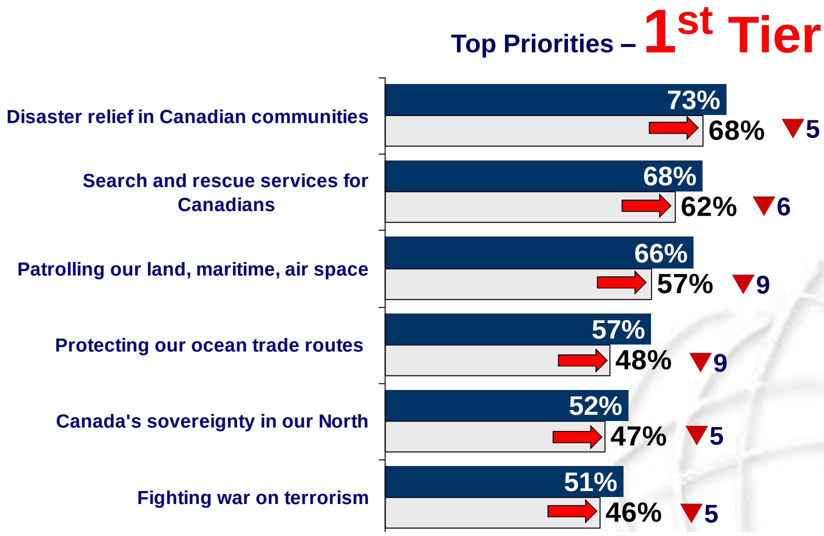
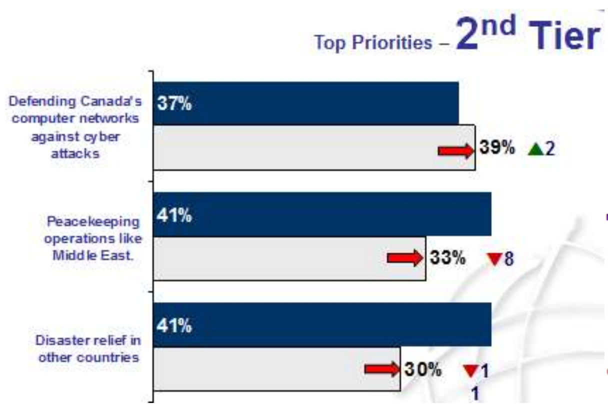


Figure 27 Analytical Hierarchy Process Threat Model Structure
Source :Finan,Illustrative Canadian Strategic Risk Assessment, 31.

APPENDIX D- IPSOS PUBLIC OPINION POLL ON CAF MISSION PRIORITIES





APPENDIX E CANADIAN DOMESTIC MARITIME OPERATING ENVIRONMENT

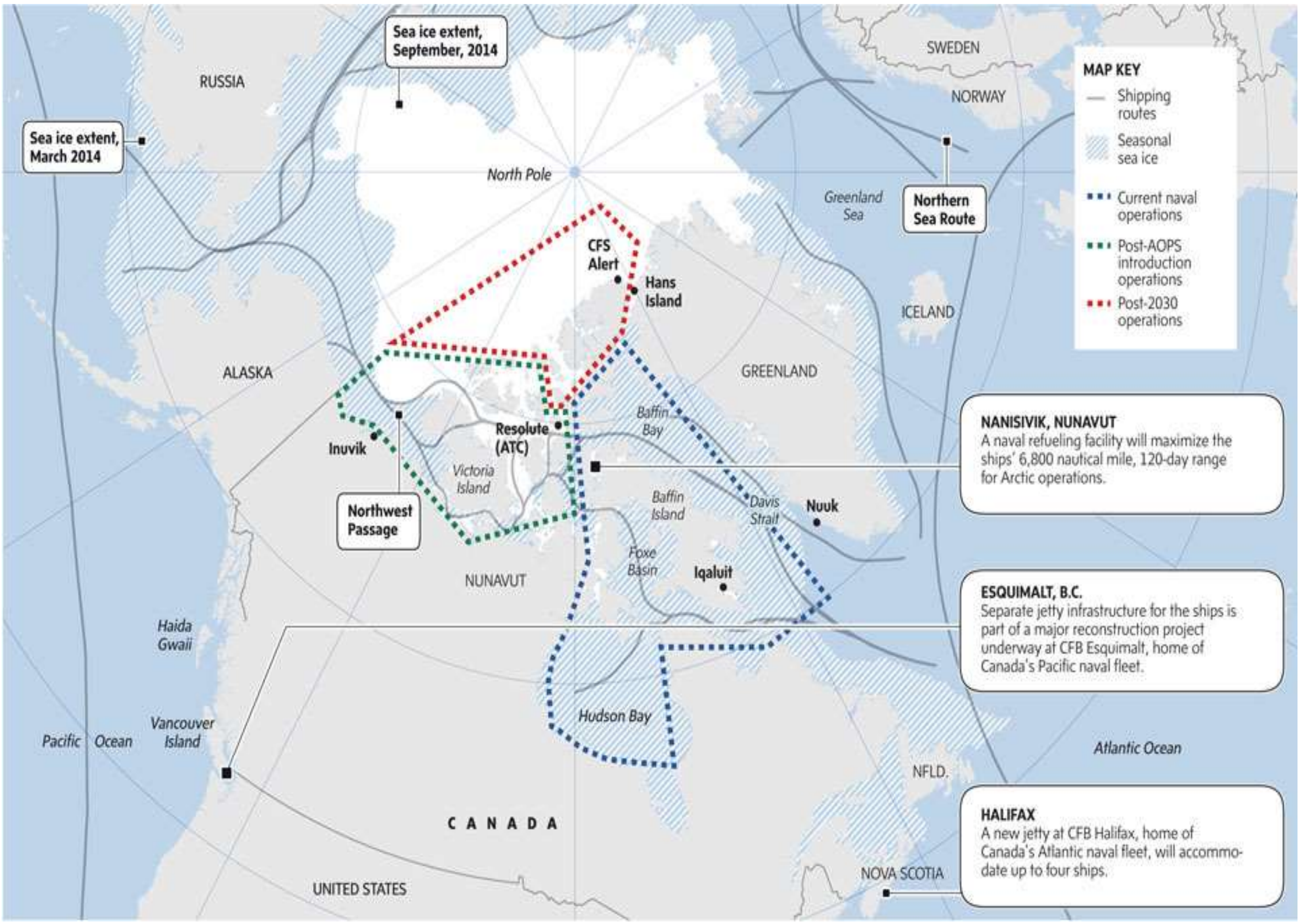


Figure 28 Artic Operating Environment
Source:Bird, Making waves, Globe & Mail.

APPENDIX F- MAJOR RCN CAPITAL PROJECTS

Table 9 Royal Canadian Navy's transition to the future fleet

Project	**Description**	**Investment**
***Halifax*-Class Modernization**	Upgrade and life-extend 12 ships	$4.2 billion modernization and re-fit
Joint Support Ship	Two new Auxiliary Oil Replenishment ships	$2.6 billion acquisition $4.5 billion personnel, operations and maintenance
Canadian Surface Combatant	Up to 15 new ships (to replace destroyers and frigates)	$26.2 billion acquisition $64 billion personnel, operations and maintenance
Arctic/Offshore Patrol Ships	Six to eight new ships	$3.1 billion acquisition $5.5 billion for personnel, operation, and maintenance
CP-140 Maritime Patrol Aircraft Modernization	Upgrade and life-extension of 14 aircraft	$2 billion for modernization and life-extension
CH-148 Cyclone Maritime Helicopter	Delivery of 28 state-of-the-art, combat-capable CH-148 Cyclone helicopters	$1.9 billion for acquisition $5.7 billion for in-service support
Naval Engineering Test Establishment	Operational contract of Naval Engineering Test Establishment for 15 years	$600 million
Maritime Coastal Defence Vessel Sonar Technology	Repair and upgrade of four deployable sensor systems	$13.4 million
***Victoria*-Class Submarines**	Refit and maintenance of the submarine fleet	Up to $1.5 billion over a period of up to 15 years for the in-service support for the Victoria-class submarines

Source:Department of National Defence, http://news.gc.ca/web/article-en.do?nid=886119.

APPENDIX G NATO FLEET SIZES 1995-2013

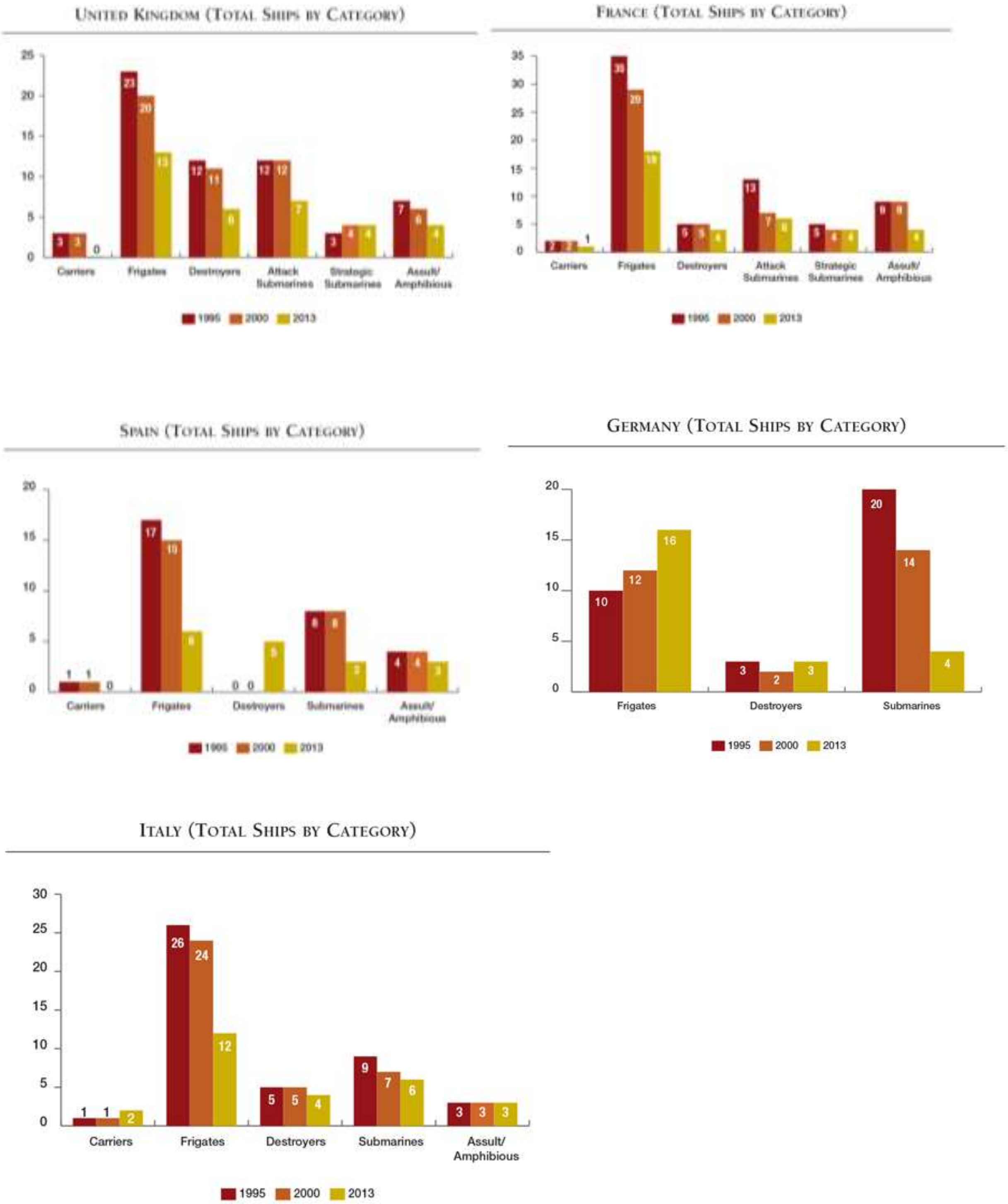


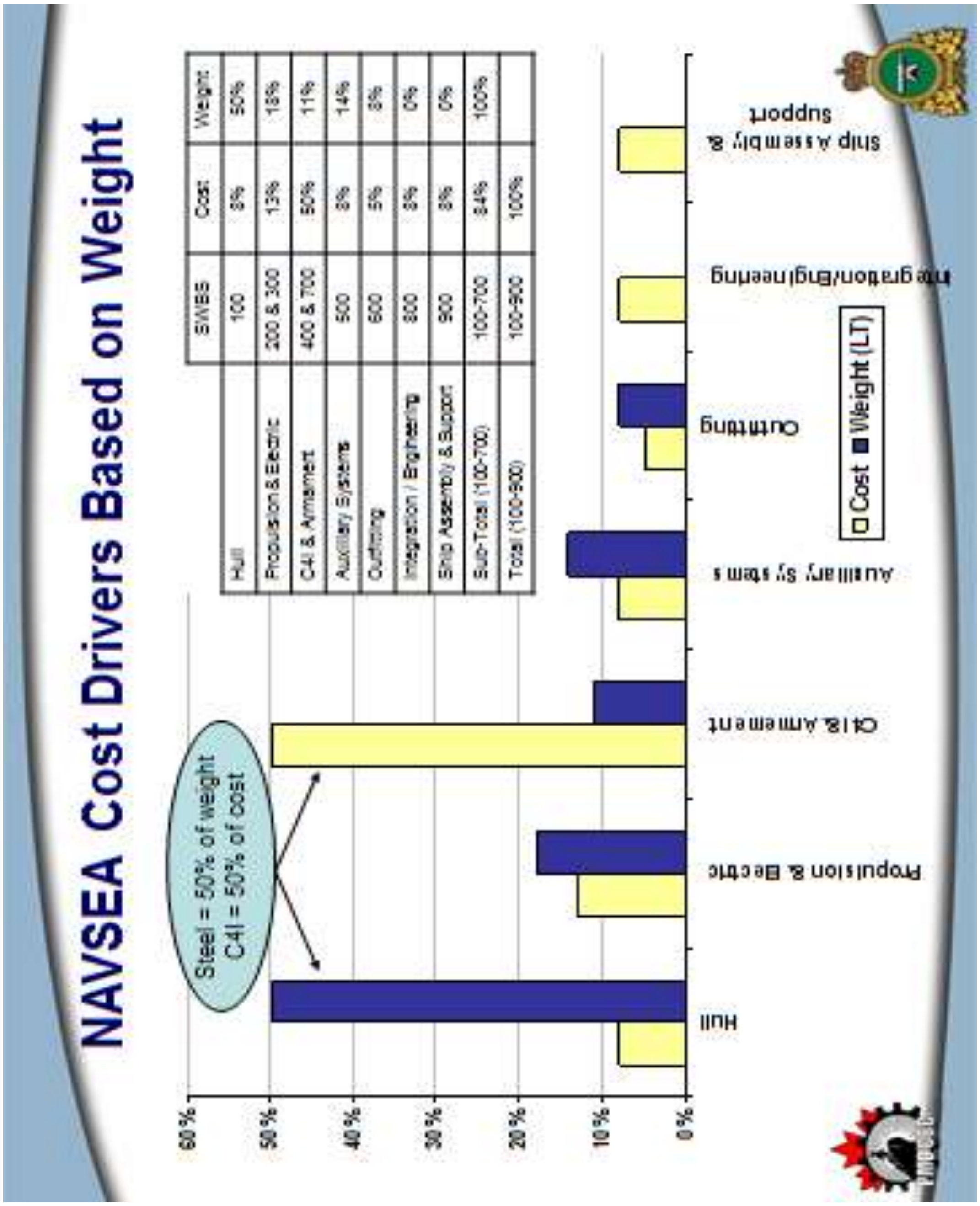
Figure 29 Allied Fleet Sizes
Source:McGrath, NATO at Sea: Trends in Allied Naval Power.

APPENDIX H USN FLEET BALANCE COMPARISON BY MAJOR REVIEW

Ship Type	Navy's 306-ship goal of March 2012	Bottom-Up Review (BUR) (1993)	2010 QDR Independent Review Panel (July 2010)
SSBNs	12-14	18	14
		(SSBN force was later reduced to 14 as a result of the 1994 Nuclear Posture Review)	
SSGNs	0-4	0	4
		(SSGN program did not yet exist)	
SSNs	~48	45 to 55	55
		(55 in FY99, with a long-term goal of about 45)	
Aircraft carriers	11 active	11 active + 1 operational/reserve	11 active
Surface combatants	~145	124	n/a
		(114 active + 10 frigates in Naval Reserve Force; a total of 110-116 active ships was also cited)	
Cruisers and destroyers	*~90*	*n/a*	*n/a*
Frigates	*0*	*n/a*	*n/a*
	(to be replaced by LCSs)		
LCSs	*~55*	*0*	*n/a*
		(LCS program did not exist)	
Amphibious ships	~32	41	n/a
	(30 operational ships needed to lift 2.0 MEBs)	(Enough to lift 2.5 MEBs)	
Dedicated mine warfare ships	0	26	n/a
	(to be replaced by LCSs)	(LCS program did not exist)	
CLF ships	~29	43	n/a
Support ships	~33	22	n/a
TOTAL ships	**~306**	**346**	**346**
		(numbers above add to 331-341)[a]	

Source: O'Rourke, Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress,54.

APPENDIX I NEW BUILD COST DRIVERS



Source: PMO CSC, Briefing to CMS.

APPENDIX J- DISTRIBUTED OFF-BOARD EFFECTS

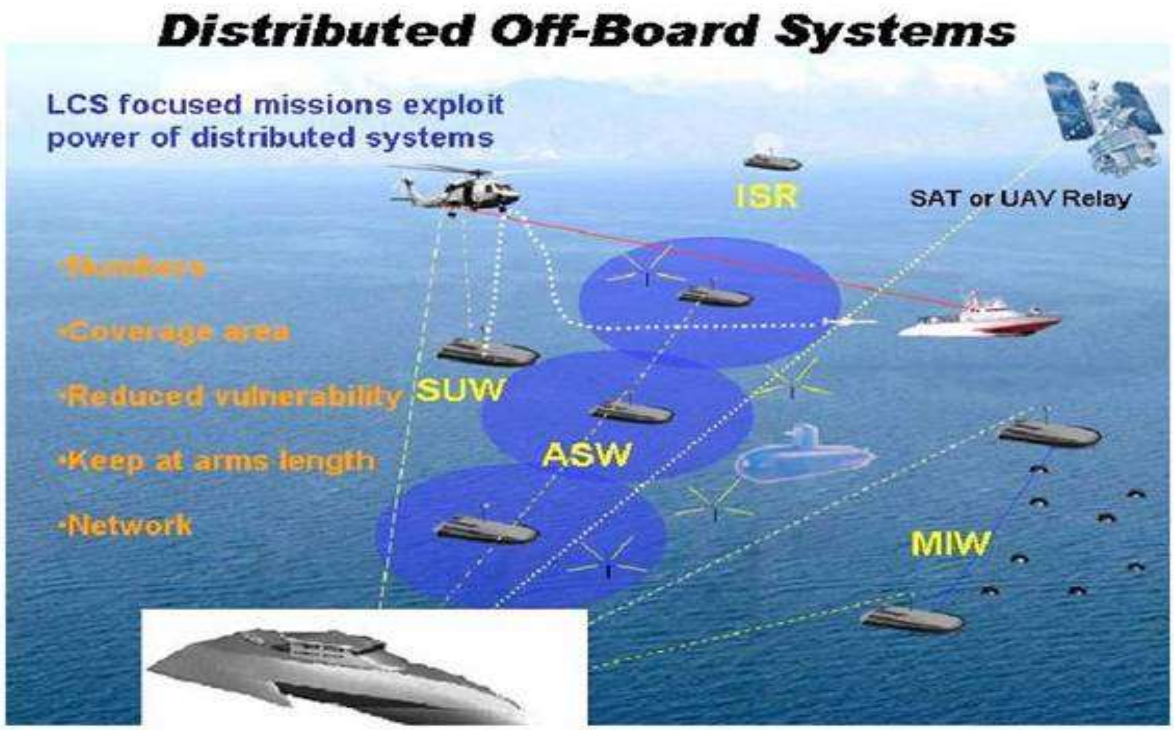
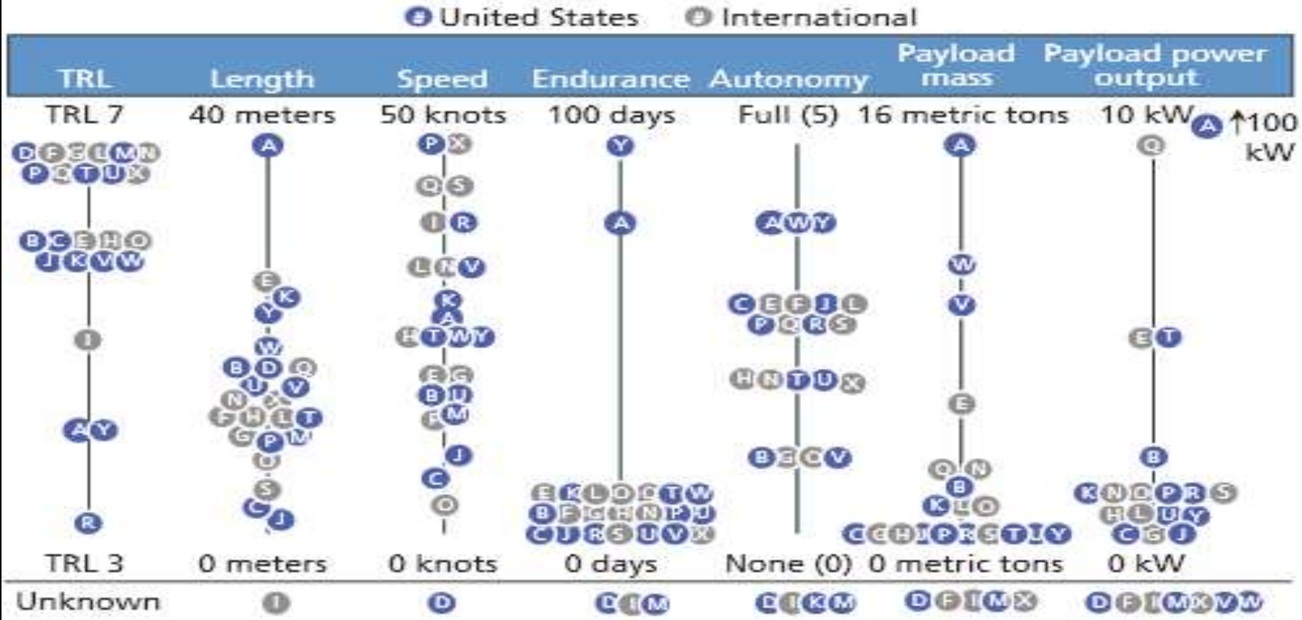


Figure 30 Distriuted Off-Board Systems
Source: Navy Warfare Development Command. 2003. Littoral Combat Ship, Concept of Operations Development.

APPENDIX K- ALLIED EMERGING USV PROLIFERATION



Letter	Vehicle name	Manufacturer name	Country of manufacture
A	ACTUV	DARPA	United States
B	ASW-USV	Willard Marine	United States
C	AutoCat	MIT AUV Labs	United States
D	Common USV	AAI Textron	United States
E	Espadon/Swordfish	DCNS	France
F	FAST	Atlas Elektronik UK	United Kingdom
G	Inspector Mk1	ECA	France
H	Inspector Mk2	ECA	France
I	Mako	Meggitt Training Systems	Canada
J	MUSCL	NSWC	United States
K	Piranha	Zyvex	United States
L	Rheinmetall USV	Rheinmetall	Germany
M	RMMV	Lockheed Martin	United States
N	Rodeur	Sirenha	France

Letter	Vehicle name	Manufacturer name	Country of manufacture
O	SARPAL	International Submarine Engineering	Canada
P	Sentinel	AAC/Brunswick	United States
Q	Silver Marlin	Elbit	Israel
R	SPICE	NAVSEA	United States
S	Stingray	Elbit	Israel
T	UISS	Oregon Iron Works	United States
U	U-Ranger	Calzoni/L3	United States
V	USSV-HS	Maritime Applied Physics Corporation	United States
W	USSV-HTF	Maritime Applied Physics Corporation	United States
X	Venus	ST Electronics	Singapore
Y	X-3 Trimaran	Harbor Wing	United States

NOTE: To indicate the level of autonomy at which a USV can perform, we used the following scale:

- Level 0: No autonomy (fully remote-controlled)
- Level 1: Rudimentary semiautonomy (waypoint navigation without collision avoidance)
- Level 2: Semiautonomous (waypoint navigation including collision avoidance)
- Level 3: Advanced semiautonomy (generates best course to target)
- Level 4: Autonomous under most conditions (application-driven)
- Level 5: Fully autonomous under all conditions (application-driven)

Source: Savitz, U.S. Navy Employment Options for Unmanned Surface Vehicles (USVs), 103.

APPENDIX L - COMPARATIVE COST OF CAS IN AFGHANISTAN

Aircraft	Purchase Cost (2012 Dollars)+	Operating Cost / Hour (Time) ++	Rough Cost for 1 Mission – AF definition*	Rough Cost for 2 Fighters or 1 Bomber**	Air Force Inventory (Active, Guard, Reserve)
A-10	$23M	$17,716/hr	$106,296	$212,592	343
AC-130U	$221M	$45,986/hr	$275,916	$275,916	35
B-1B	$399M	$57,807/hr	$571,133	$571,133	66
B-2A	$1,627M	$169,313/hr	$1,672,812	$1,672,812	20
B-52H	$84M	$69,708/hr	$688,715	$688,715	76
F-15E	$44M	$36,343/hr	$218,058	$436,116	219
F-16D	$26M	$30,357/hr	$182,142	$364,284	1,018
F-22	$168M	$68,362/hr	$410,172	$820,344	183
KC-10	$125M	$21,170/hr			59

COUNCIL on FOREIGN RELATIONS

Visualization developed by Emerson Brooking, *Defense in Depth*, Council on Foreign Relations. Dataset compiled by Ben Fernandes. Sources: Air Force Fact Sheets; Air Force Comptroller Data, summarized by *Time* Magazine.

+Purchase costs based on Air Force Fact sheets valued in constant 2012 dollars. Assumption that Air Force Fact sheet data for A-10 and F-22 as well as the Navy fact sheet used current year dollars for the published date; adjusted to 2012.

++Hourly flight costs based on Air Force Comptroller Data, summarized by *Time* Magazine.

*Rough cost of 1 CAS mission in AFG based on the hourly cost and the Air Force definition of 1 mission as 6 hours coverage for a bomber and 3 hours coverage for 2 fighters. Bomber costs assume Qatar-based bombers flying missions in AFG with an extra 3.88 hours transit time per mission. This is the same definition the Air Force uses to calculate that A-10s fly only 24 percent of CAS missions in AFG.

**Some may argue one bomber should equal two fighters due to a bomber's greater payload despite a fighter's strafing capability or the ability to cover two different locations. Accounts for additional flight time but not additional tanker costs. All platforms use tankers, though A-10 and AC-130 consume far less fuel per hour.

Source: Fernandes, The Air Force's Argument to Retire the A-10 Warthog Doesn't Add Up. Here's Why.

APPENDIX M- LIFE CYCLE COST OF VARIOUS NAVY SHIPS

	MCM-1 Class	FFG-7 Class (LAMPS III variant)	DDG-51 Class (Flight IIA)	CG-47 Class (Upgraded)	LCS-1 Low Speed Profile[a]	LCS-1 Moderate Speed Profile[a]	LCS-1 High Speed Profile[a]	LCS-2
Ship Characteristics								
Weight (Full-load displacement in tons)	1,400	4,100	9,500	10,000	3,100	3,100	3,100	2,800
Crew Size[b]								
Officers	8	11	24	24	11	11	11	11
Enlisted personnel	76	170	254	340	43	43	43	43
Total	**84**	**181**	**278**	**364**	**53**	**53**	**53**	**53**
Number of Ships	14	30	34	22	1	1	1	1
Expected Service Life (Years)	30	30	35[c]	35	25	25	25	25
Ship Costs								
Life-Cycle Cost per Ship (Outlays in millions of 2010 dollars)[d]								
R&D[e]	3	2	72	8	20	20	20	20
Procurement[f]	274	662	1,484	2,014	680	680	680	721
Personnel	243	510	897	1,156	161	161	161	161
Fuel	8	125	331	364	79	112	215	n.a.
Other O&S[g]	103	201	258	489	89	89	89	n.a.
Disposal[h]	0	0	*	*	0	0	0	0
Total	**631**	**1,500**	**3,042**	**4,032**	**1,029**	**1,063**	**1,165**	**n.a.**
Average Life-Cycle Cost per Year (Outlays in millions of 2010 dollars)[d]	21	50	87	115	41	43	47	n.a.

	MCM-1 Class	FFG-7 Class (LAMPS III variant)	DDG-51 Class (Flight IIA)	CG-47 Class (Upgraded)	LCS-1 Low Speed Profile[a]	LCS-1 Moderate Speed Profile[a]	LCS-1 High Speed Profile[a]	LCS-2
Ship Costs (Continued)								
Breakdown of Life-Cycle Cost per Ship (Percent)[d]								
R&D[e]	*	*	2	*	2	2	2	n.a.
Procurement[f]	43	44	49	50	66	64	58	n.a.
Personnel	38	34	29	29	16	15	14	n.a.
Fuel	1	8	11	9	8	11	18	n.a.
Other O&S[g]	16	13	8	12	9	8	8	n.a.
Disposal[h]	0	0	*	*	0	0	0	n.a.
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**n.a.**

Figure 31 USN ship life-cycle costs
Source: Congressional Budget Office

APPENDIX N- CHARACTERISTICS OF SHARED BUILD PROJECTS

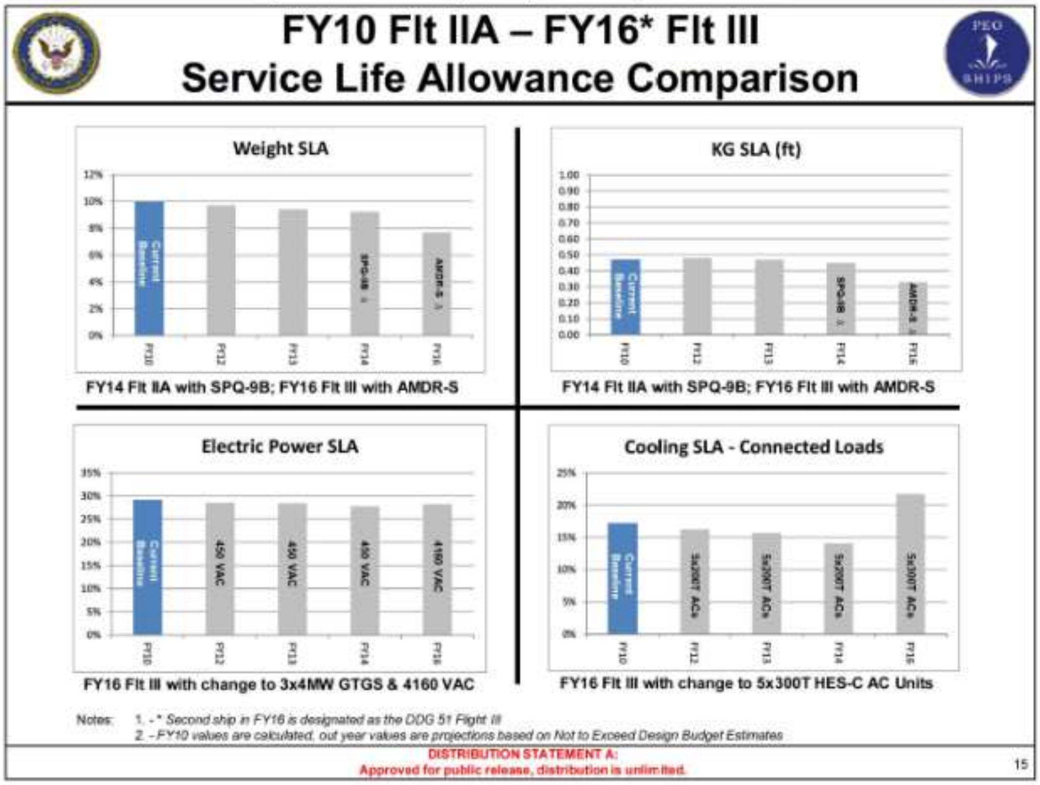
Characteristics of Shared-Build Programs Studied

Characteristic	*Virginia* Class	DDG-1000	LPD-17	DDG-51 Deckhouse	Type 45	QEC	*Mistral* Class
Number of units	30	3	9	1	6	2	3
Choice of shared build	Maintain industrial base	Access specialist skills	Event-constrained capacity	Event-constrained capacity	Maintain industrial base	Overcome capacity restrictions	Overcome capacity restrictions and reduce costs
Capability constraints	Ring construction; sustain two yards' ability to integrate and deliver alternate assembly and delivery, alternate construction of nuclear reactor, and split rest of modules evenly	Composite deckhouse to NGSB-GC; rest to BIW	Reduced capability (loss of labor and facilities) after Hurricane Katrina; outsource some steel work and minor outfitting to small companies	Build yard had no "spare" deckhouse modules; use deckhouse already being built in BIW	N/A; distribute work to minimize cost	QEC project too large for single shipyard; distribute work to minimize cost	DCN yard could not build whole ship. Chantiers de l'Atlantique yard is skilled at large-accommodation construction: living spaces to Chantiers; combat systems and other military functions to DCN; some outsourcing of DCN steel work to Polish yard
Contractual arrangements	Intimate teaming, prime-sub	GFE	Prime-sub	GFE	Prime-sub	Alliance	Prime-sub
Design software and IT	Shared design system, separate business systems	Shared design systems	N/A	N/A	Separate design systems	Shared data warehouse, two separate design systems	Separate
Cost implications	Transportation costs; IT infrastructure costs; additional design-translation cost	Transportation costs; IT infrastructure costs for common data systems	Transportation costs	Transportation costs	Transportation costs	Transportation costs; IT infrastructure costs; infrastructure-modification costs	Transportation costs

Source: Smallman, Shared Modular Builds of Warships, 28.

APPENDIX O DDG-51 COMPARATIVE GROWTH MARGINS

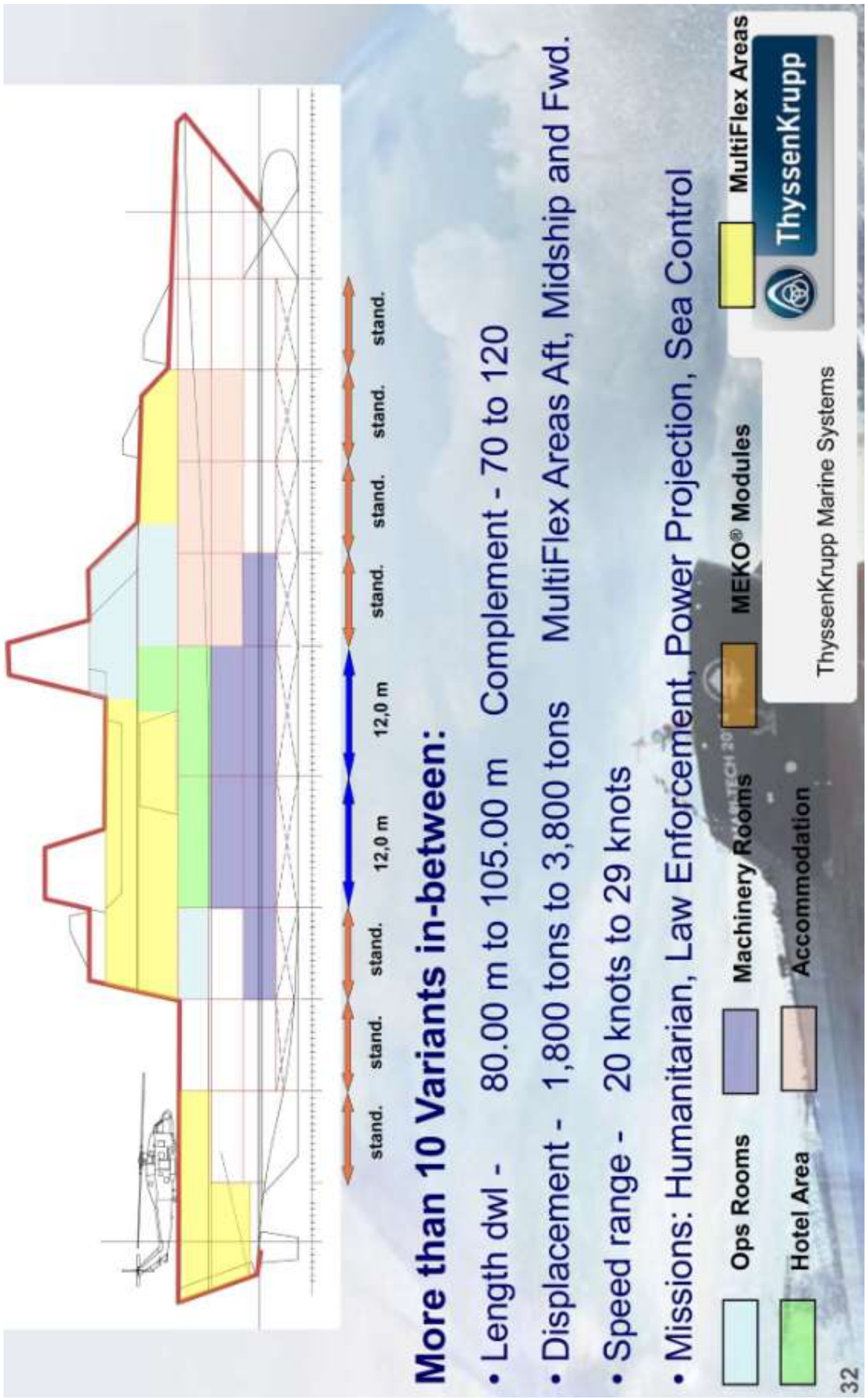
Flight III DDG-51 Design Compared to Flight IIA DDG-51s



Source: Presentation of Captain Mark Vandroff to Surface Navy Association, January 15-17, 2013; a copy of the slides was provided to CRS by the Navy Office of Legislative Affairs on January 28, 2013.

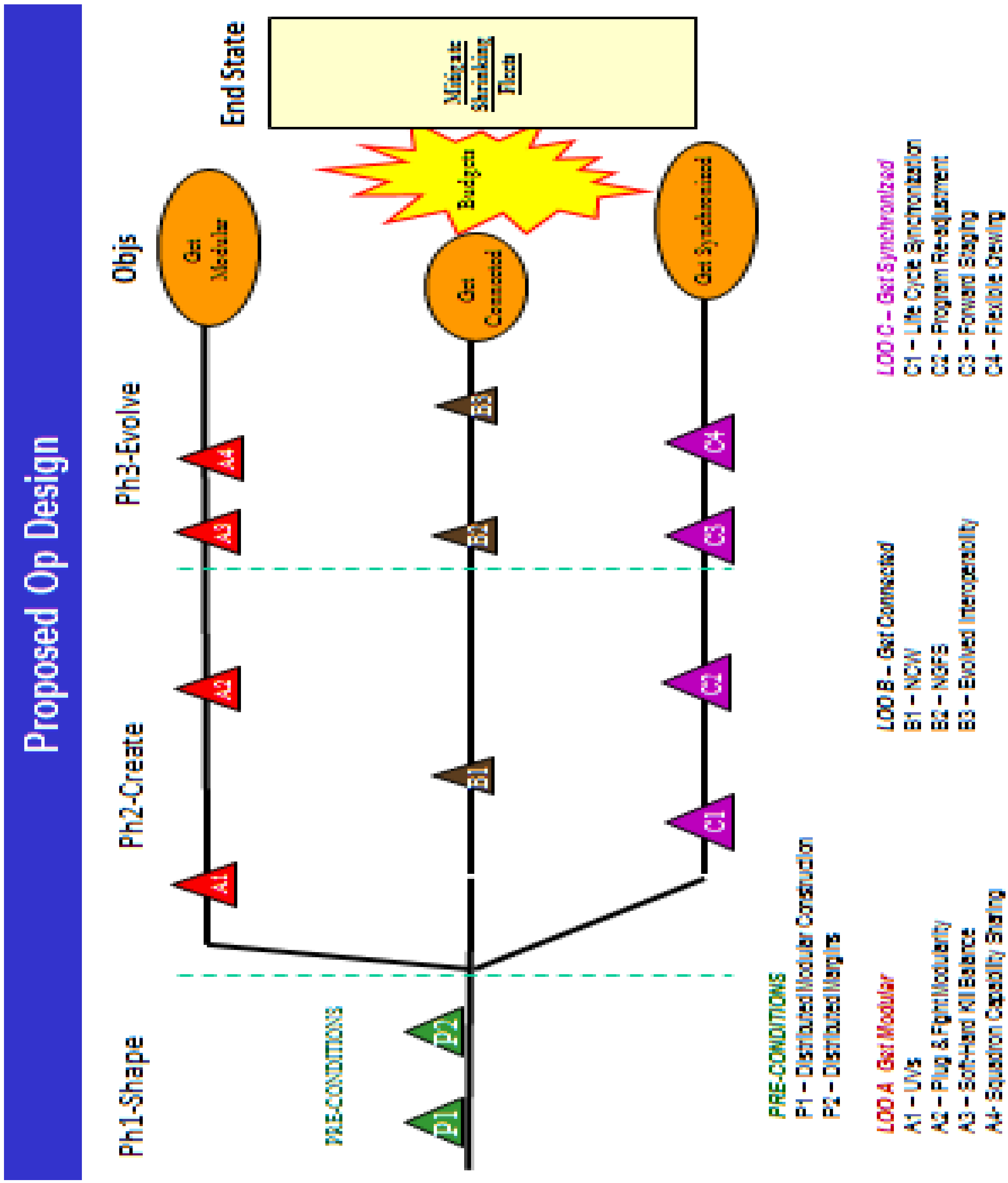
Note: SLA means service life allowance (i.e., growth margin).

APPENDIX P-MEKO FLEX RANGE OF APPLICATION



Source: Bern, Addressing the challenges of modern warship design, Mari-Tech 2014 Conference proceedings.

APPENDIX Q COST SAVING STRATEGY OP DESIGN



APPENDIX R VIRTUAL FLEET JUSTIFICATION PARAMETERS

	MH	AOPS	MCDV	SSK	JSS	C2AD	GP
CFDS	15	8	12	4	3	3	12
PC	N/A: Maritime Helos already being built.	Applicable: Proposed design is a 6000t ship with plenty of residual space	N/A: Already built with limited growth potential	N/A: Already built with limited growth potential	Applicable: Berlin Class has plenty of additional margins built in	Applicable: Not designed yet, potential remains	Applicable: Not designed yet, potential remains
LOO A	Applicable: MH designed with plug& fight capability. Mission packages to be delivered beyond 2017	Applicable: Proposed design shows potential for Plug & Fight adoption[141]	N/A: Already built with limited plug& fight adoption beyond current employment scheme	N/A: Already built no plug & fight potential	N/A: Already designed with limited plug & fight potential beyond modular hospital	Applicable: Not designed yet, potential remains	Applicable: Not designed yet, potential remains
LOO B	N/A: Link16 planned however does not compare to the CEC as discussed in chapt 2	Applicable: Could incorporate passive CEC system akin to ADSI system employed on IRO Class in early 2000s	N/A: would require a complete command and control system overhaul, cost would not justify ROI	N/A: unproven and difficult to perform underwater	N/A: not a combatant and therefore limited applicability	Applicable: Not designed yet, potential remains	Applicable: Not designed yet, potential remains
LOO C	Applicable: Air Force already employs flex crewing with multiple aircrews assigned to ships	Applicable: Independent from design, force employment measure	Applicable: Independent from design, force employment measure	Applicable: Independent from design, force employment measure	Applicable: Independent from design, force employment measure	Applicable: Independent from design, force employment measure	Applicable: Independent from design, force employment measure

PRE-CONDITIONS
P1 – Distributed Modular Construction
P2 – Distributed Margins

LOO A Get Modular
A1 – UVs
A2 – Plug & Fight Modularity
A3 – Smart Kill Balance
A4- Squadron Capability Sharing

LOO B – Get Connected
B1 – NCW
B2 – NGFS
B3 – Evolved Interoperability

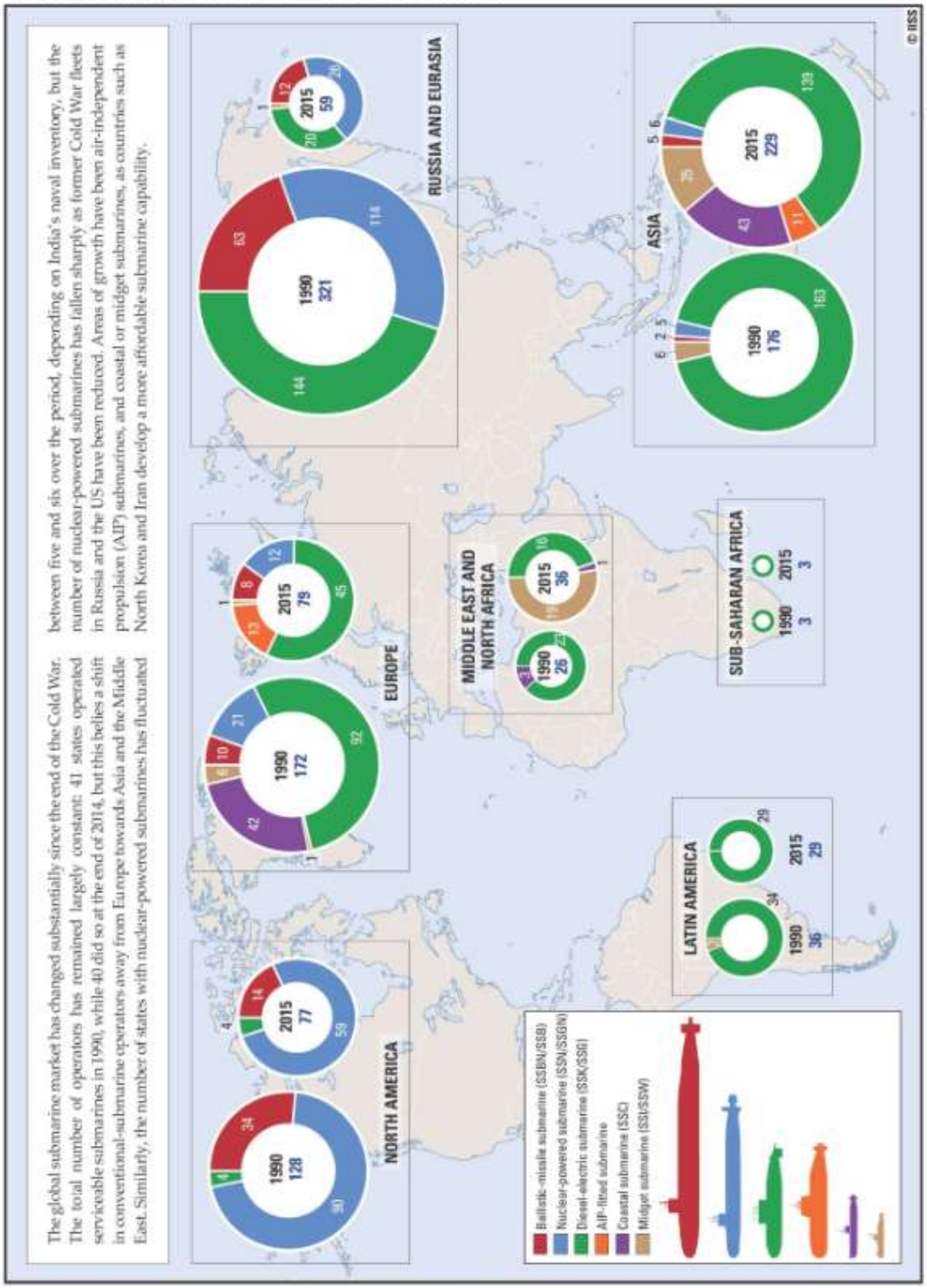
LOO C – Get Synchronized
C1 – Life Cycle Synchronization
C2 – Program Re-adjustment
C3 – Forward Staging
C4 – Flexible Crewing

---

[141] Michael Bird, "Making Waves: The Navy's Arctic Ambition Revealed," http://www.theglobeandmail.com/news/national/the-navys-arctic-ambition/article23290380/.

APPENDIX S CHANGES IN THE GLOBAL SUBMARINE MARKET SINCE 1990

Changes in the global submarine market since 1990



Source: The Military Balance 2015, 23.

BIBLIOGRAPHY

"Balisle Highlights Adaptability and Modularity of DD(X) and LCS Programs." *Defense Daily* 219, no. 46 (Sep 4, 2003): 1.

"Cebrowski: Today's Thinking Won't do for Tomorrow's Navy." *Defense Daily* 204, no. 23 (Nov 3, 1999, 1999): 1.

"CSBA Report Identifies Questions regarding Modularity for LCS." *Defense Daily* 221, no. 32 (Feb 20, 2004): 1.

"Impact of Mission Modularity on a Naval Ship's Life Cycle Cost." *MENA Report* (Apr 5, 2014).

"Keeping a Cutting Edge: New Threats, Technologies, and Business Models for NATO Underwater Research." *Jane's Navy International* 119, no. 5 (Jun 1, 2014).

"LCS Will Require Navy to Examine Future of Small Crews and Modularity." *Defense Daily* 228, no. 25 (Nov 10, 2005): 1.

"Littoral Combat Ship's Modularity - the Shape of Things to Come for Navy." *Defense Daily* 229, no. 36 (Feb 24, 2006): 1.

"Make Or Break Year? the US Navy's Littoral Combat Ship Programme in 2014." *Jane's Navy International* 119, no. 3 (Apr 1, 2014).

"The Military Balance 2015." *Iiss* 115, no. 1 (01/01; 2015/04).

"Modular Warship Concepts: Is 'Plug and Fight' here to Stay?" *Jane's International Defense Review* 46, no. 9 (Sep 1, 2013).

"Modularity a Key to Future Submarine Capability and Affordability." *Defense Daily* 206, no. 55 (Jun 19, 2000): 1.

"Opinion - LCS: The US Navy's 'Disruptive' Warship." *Jane's Defence Weekly* 50, no. 12 (Feb 20, 2013).

"Third Fleet Hosts Standard Task Force Structure Workshop." *Targeted News Service,* Sep 3, 2010.

"Without Resources Navy's Fleet Structure could be in Jeopardy, Report Claims." *Defense Daily* 230, no. 45 (Jun 5, 2006): 1.

Aikire, Brien. *Littoral Combat Ships: Relating Performance to Mission Package Inventories, Homeports, and Installation Sites*. Santa Monica, CA: RAND Corporation, 2007.

Alkire, Brien. *Applications for Navy Unmanned Aircraft Systems*. Rand Corporation Monograph Series. Santa Monica, CA: Rand Corporation, 2010.

Allen, D. and D. Blakeney. *Fleet Mix Study: Determining the Required Capacity and Capability of the Future Surface Naval Force Structure* . DRDC CORA Technical Report. Vol. 2005-38. Ottawa: Centre for Operational Research and Analysis, Defence R&D Canada, 2005.

Alper, Omer and W. Brent Boning. *Selected Developments in Commercial and Navy Acquisition Practices*. Alexandria, Va.: Center for Naval Analyses, 2003.

Arena, Mark V. *Why has the Cost of Navy Ships Risen?: A Macroscopic Examination of the Trends in U.S. Naval Ship Costs Over the Past several Decades*. Santa Monica, CA: RAND, 2006.

Arena, Mark V., John Birkler, John F. Schank, Jessie Riposo, and Clifford A. Grammich. *Monitoring the Progress of Shipbuilding Programmes: How can the Defence Procurement Agency More Accurately Monitor Progress?*: RAND, Santa Monica, CA, 2005.

Badescu, Cristina G. "Canada's Continuing Engagement with the United Nations Peace Operations." *Canadian Foreign Policy* 16, no. 2 (Spring 2010): 45-IV.

Barfoot, C. B. "Crisis Response:Analysis of Historical Data." *Center for Naval Analysis* (1997).

Bird, Michael. "Making Waves: The Navy's Arctic Ambition Revealed." http://www.theglobeandmail.com/news/national/the-navys-arctic-ambition/article23290380/.

Bourque, Alex and Cheryl Eisler. *Fleet Mix Study Iteration II: Making the Case for the Capacity of the "Navy After Next"*. DRDC CORA Technical Report. Vol. 2010-159. Ottawa: Centre for Operational Research and Analysis, Defence R&D Canada, 2010.

Bourque, Alex and Ramzi Mirshak. *Effects of Platform Numbers on the Projected Capacity of the Canadian Surface Combatant Fleet*. Ottawa: DRDC CORA, 2015.

Business Monitor International. "Canada Defence and Security Report 2015." (2015).

Button, Robert. *Maritime Prepositioning Force (Future) Capability Assessment: Planned and Alternative Structures*. Santa Monica, CA: RAND, 2010.

———. *Small Ships in Theater Security Cooperation*. Santa Monica, CA: RAND Corporation, 2008.

Canada. Department of National Defence. "Operation IMPACT: Air Task Force-Iraq Airstrikes." http://www.forces.gc.ca/en/operations-abroad-current/op-impact-airstrikes.page.

———. *Statement of Requirements: Canadian Surface Combatant Draft* 2014.

Canada. Department of National Defence, Chief of Force Development. *Capability-Based Planning Handbook* 2014.

Canada. Department of National Defence, Directorate of Maritime Strategy. *Leadmark: The Navy's Strategy for 2020*. Ottawa: Directorate of Maritime Strategy, NDHQ/Chief of the Maritime Staff, 2001.

———. *Securing Canada's Ocean Frontiers: Charting the Course from Leadmark*. Canadian Forces Publication. Ottawa: Directorate of Maritime Strategy, NDHQ/Chief of the Maritime Staff, 2005.

Canada. Department of National Defence, PMO CSC. *Options Analysis Brief to CMS*. Ottawa Canada: 2009.

Canada. Public Works and Government Services. "National Shipbuilding Procurement Strategy." http://www.tpsgc-pwgsc.gc.ca/app-acq/sam-mps/snacn-nsps-eng.html.

———. "Technology Readiness Level." https://buyandsell.gc.ca/initiatives-and-programs/build-in-canada-innovation-program-bcip/program-specifics/technology-readiness-levels.

Canadian Forces College and College des Forces Canadiennes. *CFC Guide to CF Operational Planning Process*. Cfc 230. Toronto, ON: Canadian Forces College, 2008.

Choi, Jino, Omer Alper, James Jondrow, John Keenan, Richard Sperling, and Michael Gessner. *Improving Navy's Buying Power through Cost Savings*. Alexandria, Virginia: Center for Naval Analysis, 2006.

Clark, Brian. "Commanding the Seas: A Plan to Reinvigorate US Navy Surface Warfare." *CSBA* (2014).

Daniels, Sharon. "Alternative Crewing Strategies." *United States Naval Institute.Proceedings* 131, no. 11 (Nov 2005): 77-78.

Eckstein, Megan. "USS Fort Worth Successfully Tested Overseas Maintenance Outside of Singapore Hub." USNI News. http://news.usni.org/2015/04/13/uss-fort-worth-successfully-tested-overseas-maintenance-outside-of-singapore-hub.

Elmendorf, Douglas. "Life Cycle Cost of various Navy Ships." *Congressional Budget Office* (2010).

Fein, Geoff. "USN Official Says Surface Ship Designs must be More Flexible to Maximise Service Life." *Jane's Navy International* 120, no. 4 (May 1, 2015).

———. "USN S&T Research Strategy to Focus on New Weapons, Unmanned Systems, and Cyber." *Jane's Navy International* 120, no. 4 (May 1, 2015).

Fernandes, Ben. "The Air Force's Argument to Retire the A-10 Warthog Doesn't Add Up. Here's Why." http://blogs.cfr.org/davidson/2015/03/05/the-air-forces-argument-to-retire-the-a-10-warthog-doesnt-add-up-heres-why/.

Finan, J. S. and W. D. Macnamara. "An Illustrative Canadian Strategic Risk Assesment." *Canadian Military Journal* (2001).

Freedberg, Sydney. "You Spot I Shoot: Aegies Ships Share Data to Destroy Cruise Missile." Breaking Defense. http://breakingdefense.com/2014/10/you-spot-i-shoot-2-navy-aegis-ships-with-sm-6-kill-target-together/.

Frost, Laurence, Cremer, Andreas and Lienert, Paul. "Insight: Has Volkswagen Discovered the Holy Grail of Carmakers?" Reuters. http://www.reuters.com/article/2013/02/11/us-autos-volkswagen-future-idUSBRE91A04D20130211.

Galdorisi, George and R. Robinson Harris. "Modularity Will Help Protect the Maritime Commons." *United States Naval Institute.Proceedings* 137, no. 12 (Dec 2011): 76-77.

Gonzales, Daniel and Sarah Harting. *Designing Unmanned Systems with Greater Autonomy: Using a Federated, Partially Open Systems Architecture Approach*. Rand Corporation. Vol. RR-626-OSD. Santa Monica, CA: RAND Corporation, 2014.

Goodlad, Ben. "Analysis: NATO's Precision Munition Procurement Set to Soar Over Next Decade." *Jane's Defence Weekly* 49, no. 20 (Apr 25, 2012).

Goure, Daniel. "Modularity, the Littoral Combat Ship and the Future of the United States Navy." *Lexington Institute* (2006).

Gouré, Daniel, Dewey Mauldin, and John Kreul. *Naval Forward Presence ; Present Status, Future Prospects: A Report on the CSIS Conference on Naval Forward Presence*. Washington, D.C.: Center for Strategic & International Studies, 1997.

Gouré, Daniel and Jeffrey M. Ranney. *Averting the Defense Train Wreck in the New Millennium*. CSIS Report. Washington, DC: Center for Strategic and International Studies, 1999.

Grace, Jean. "Navy League 2015: USN Establishing Office to Oversee Unmanned Systems." *Jane's Defence Weekly* 52, no. 22 (Apr 15, 2015).

———. "RIMPAC 2014: Littoral Combat Ship Works with Special Forces to Demonstrate Afloat Staging Base Capacity." *Jane's Navy International* 119, no. 6 (Aug 1, 2014).

———. "Surface Navy 2015: Future Threats Will See Surface Forces Recoup Offensive Capability, Says USN." *Jane's Navy International* 120, no. 1 (Feb 1, 2015).

———. "A Team Sport: Canada Continues its Surface Fleet Renewal." *Jane's Navy International* 120, no. 4 (May 1, 2015).

Great Britain. Ministry of Defence. *Future 'Black Swan' Class Swoop-of-War: A Group System*. Jdn 1/12. Vol. 1/12. Shrivenham, Swindon: Joint Doctrine & Concepts Centre, 2012.

Great Britain. Royal Navy and Great Britain. Defence Council. *British Maritime Doctrine*. Book of Reference. 3rd ed. Vol. 1806. London: Naval Staff Directorate, distributed by the Stationary Office, 2004.

Griffiths, Franklyn, P. W. Lackenbauer, and Robert N. Huebert. *Canada and the Changing Arctic : Sovereignty, Security, and Stewardship*. Waterloo, Ont: Wilfrid Laurier University Press, 2011.

Harding, Thomas. "Cutting Missile System Leaves Warships at Risk [Edition 2]." *The Daily Telegraph,* Jun 9, 2012.

Hattendorf, John B. "The Idea of a "Fleet in being" in Historical Perspective." *Naval War College Review* (2014).

Horan, D. J. *A Vulnerable Royal Canadian Navy: The National Shipbuilding Procurement Strategy and the Threat to the Navy's Long Term Vision*. Masters Thesis (Canadian Forces College). Vol. JCSP/PCEMI 39-35. Toronto, Ont.: Canadian Forces College, 2013.

Hughes, Wayne P. *Fleet Tactics and Coastal Combat*. 2nd ed. Annapolis, Md.: Naval Institute Press, 2000.

Kulmus, Bernd. "Addressing the Challenges of Modern Warship Design: Blohm+Voss Meko Flex" Niagara Falls, Canada, Mari-Tech Seminar, 2014, 2014.

Lambert, Nicholas A. *The Submarine Service, 1900-1918*. Publications of the Navy Records Society. Vol. ol. 142. Aldershot, Hants, England ; Burlington, Vt.: Published by Ashgate for the Navy Records Society, 2001.

Lind, William S. *Maneuver Warfare Handbook*. Westview Special Studies in Military Affairs. Boulder, Colo.: Westview Press, 1985.

Mamuji, Aaida. "Canadian Military Involvement in Humanitarian Assistance: Progress and Prudence in Natural Disaster Response." *Canadian Foreign Policy (CFP)* 18, no. 2 (06, 2012): 208-224.

Marketwired. "Harper Government Launches New International Trade Plan." *Marketwire* (11/27, 2013).

McDonald, Art. *Identifying the Leadmark: The Canadian Navy in Support of Foreign Policy since 1945*. Masters Thesis (Canadian Forces College). Vol. CSC 29-011. Toronto, Ont.: Canadian Forces College, 2003.

McGrath, Bryan. *NATO at Sea: Trends in Allied Naval Power*: , American Enterprise Institute, 2013.

Merrick, Carey. "Modularity Times Three." *Sea Power* 40, no. 4 (Apr 1997, 1997): 81-84.

Moroney, Jennifer D. P. *How Successful are U.S. Efforts to Build Capacity in Developing Countries?: A Framework to Assess the Global Train and Equip "1206" Program*. Rand Corporation. Vol. TR-1121. Santa Monica, CA: RAND, 2011.

Muller, Albrecht. "New Frigate Underscores Germany's Shift from Cold War Naval Combat." *Defense News*, Jan 13, 2014.

Nitschke, Stefan. "Special Ship Design for Crisis Management Missions." *Naval Forces* 23, no. 6 (2002): 27-35.

Olivier, Jacques P. *Strategic Planning and Prioritization Methodology for Major Naval Surface Combatants Conceptual Design*. Masters Thesis (Canadian Forces College). Vol. JCSP/PCEMI 37-29. Toronto, Ont.: Canadian Forces College, 2011.

O'Rourke, Ronald. *Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress*: Congressional Research Service, 2013.

O'Rourke, Ronald. "Hard to Get: US Navy Faces Up to Procurement Issues." *Jane's Navy International* 114, no. 3 (2009): 32-34, 36-37.

———. . *Navy DDG-51 and DDG-1000 Destroyer Programs: Background and Issues for Congress*. CRS Report for Congress. Washington, D.C.: Congressional Research Service, Library of Congress, 2014.

———. "The Navy in a Time of Less Money." *United States Naval Institute Proceedings* 137, no. 11 (Nov 2011): 10.

———. *Navy Irregular Warfare and Counterterrorism Operations: Background and Issues for Congress* United States Foreign Press Center, 2013.

———. . *Navy Littoral Combat Ship (LCS): Issues and Background for Congress*. CRS Report for Congress. Vol. RS21305. Washington, D.C.: Congressional Research Service, Library of Congress, 2014.

———. "Navy Ship Propulsion Technologies: Options for Reducing Oil use - Background for Congress." *Star* 45, no. 19 (2007).

———. *Navy Shipboard Lasers for Surface, Air, and Missile Defense: Background and Issues for Congress* Congressional Research Reports for the People, 2010.

———. "Programs Vs. Ressources: Some Options for the Navy." *Naval War College Review* 63, no. 4 (Autumn 2010): 25-37A.

———. "U.S. Grand Strategy and Maritime Power." *United States Naval Institute.Proceedings* 138, no. 1 (Jan 2012): 46-47.

Paul, Christopher. *The RAND Security Cooperation Prioritization and Propensity Matching Tool*. RAND Corporation. Vol. TL-112-OSD. Santa Monica, CA: RAND Corporation, 2013.

———. *What Works Best when Building Partner Capacity and Under what Circumstances?*. RAND Corporation Monograph. Vol. MG-1253/1-OSD. Santa Monica, CA: RAND Corporation, 2013.

Peruzzi, Luca. "Italian Navy Anticipates Key Contracts in Fleet Renewal Process." *Jane's Navy International* 120, no. 4 (May 1, 2015).

Polmar, Norman and United States Naval Institute. *The Ships and Aircraft of the United States Fleet*. 11th ed. Annapolis, Ind.: United States Naval Institute, 1978.

Porche, Isaac, Henry Willis, and Martin Ruszkowski. *Framework for Quantifying Uncertainty in Electric Ship Design*. Documented Briefing / RAND Corporation. Vol. DB-407-ONR. Santa Monica, CA: RAND, National Defense Research Institute, 2004.

Riposo, Jessie. *U.S. Navy Shipyards: An Evaluation of Workload- and Workforce-Management Practices*. Santa Monica, CA: RAND, 2008.

Samaras, Constantine, Abigail Haddad, Clifford A. Grammich, and Katharine Watkins Webb. . *Obtaining Life-Cycle Cost-Effective Facilities in the Department of Defense*. Santa Monica, CA: RAND, 2012.

Savitz, Scott, Irv Blickstein, Peter Buryk, Robert W. Button, Paul DeLuca, James Dryden, Jason Mastbaum, et al. *U.S. Navy Employment Options for Unmanned Surface Vehicles (USVs)* RAND, 2013.

Schank, John F., Mark V. Arena, Kristy N. Kamarck, Gordon T. Lee, J. L. Birkler, Robert E. Murphy, and Roger Lough. *Keeping Major Naval Ship Acquisitions on Course: Key Considerations for Managing Australia's Sea 5000 Future Frigate Program*. Santa Monica, CA: RAND, 2014.

Schwab, Klaus. "The Global Competitiveness Report 2014-2015." *World Economic Forum* (2014).

Schwartz, Moshe, Katherine Blakeley, and Ronald O'Rourke. "Department of Defense Energy Initiatives: Background and Issues for Congress." *Congressional Research Service: Issue Brief* (07, 2012): 1-64.

Scott, Richard. "MEKO Re-Engineered for Mission Modularity." *Jane's Defence Weekly* 43, no. 40 (10/04, 2006): 48-48.

———. "UK Defence Chief Vexes on Fleet Size, Capability." *Jane's Navy International* 118, no. 1 (Feb 1, 2013).

———. "UK Looks to Examine Enhanced Active Soft-Kill Decoy." *Jane's Defence Weekly* 52, no. 9 (Jan 14, 2015).

Sherman, Jason. "Navy Sets $7.2B Price Tag for Littoral Combat Ship Mission Modules." *InsideDefense.Com's SitRep* (Apr 1, 2014).

Smallman, Lawrence, Hanlin Tang, John F. Schank, and Stephanie Pezard. *Shared Modular Builds of Warships: How a Shared Build can Support Future Shipbuilding*. Santa Monica, CA: RAND, 2011.

Standifer, Cid. "O'Rourke: Force Structure Assesment Likely to Call for 320 Or 321 Ships." *Inside the Pentagon's Inside the Navy* 24, no. 10 (Mar 14, 2011).

Steketee, Menno. "Swedish Staff and Equipment Boards Dutch LPD for EU Counter-Piracy Ops." *Jane's Navy International* (January 28, 2015, 2015).

Terino, John. "Cebrowski: Fleet Modernization Requires Procurement Changes." *Aerospace Daily & Defense Report* 213, no. 22 (Feb 3, 2005): 5.

The Congressional, Budget Office. *Options for the Navy's Future Fleet*, 2006.

Thorsteinson, Janet. "Modular Warships." *Canadian Naval Review* 8, no. 4 (2013).

Vaughan, Andrew. "Navy Low on Frigates to Ship Back HMCS Toronto Crew." Canadian Press. http://www.cbc.ca/news/canada/nova-scotia/navy-low-on-frigates-to-ship-back-hmcs-toronto-crew-1.1392444.

Work, Robert O. *The Challenge of Maritime Transformation: Is Bigger Better?*. Washington, DC: Center for Strategic and Budgetary Assessments, 2002.

———. *Know when to Hold 'Em, Known when to Fold 'Em: Thinking about Navy Plans for the Future Surface Battle Line*. Backgrounder (Center for Strategic and Budgetary Assessments (Washington, D.C.)). Washington, DC: Center for Strategic and Budgetary Assessments, 2007.

———. *Naval Transformation and the Littoral Combat Ship*. Washington, DC: Center for Strategic and Budgetary Assessments, 2004.