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STRATEGIC PLANNING AND PRIORITIZATION METHODOLOGY FOR MAJOR NAVAL SURFACE COMBATANTS CONCEPTUAL DESIGN

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ACRONYMS AND ABBREVIATIONS

AAD	Area-Air Defence
AAW	Anti-Air Warfare
AIP	Approval in Principle
ALEA	Assistance to Law Enforcement Agency
ALSC	Afloat Logistics and Sealift Capability
AOPS	Arctic/Offshore Patrol Ships
AOR	Area of Responsibility
AOR	Auxiliary Oiler Replenishment
ASDL	Aerospace Systems Design Laboratory
ASuW	Anti-Surface Warfare
ASW	Anti-Submarine Warfare
BRIC	Brazil, Russia, India, China
CAD	Canadian Dollar
CADRE	Command-and-Control and Area Air-Defence Capability Replacement
CANUS	Canada, United States
CBRN	Chemical, Biological, Radiological and Nuclear
CDF	Cummulative Distribution Function
CDR	Critical Design Review
CDS	Chief of Defence Staff
CF	Canadian Forces
CFDS	Canada First Defence Strategy
CIMIC	Civilian-Military Cooperation
CISD	Center for Innovation in Ship Design
CMS	Chief of Maritime Staff
COINOP	Counter Insurgency Operation
ConOPS	Concept of Operation
ConSP	Concept of Support
COG	Centre of Gravity
CORA	Centre of Operational Research and Analysis
COTS	Commercial off the Shelf
CPF	Canadian Patrol Frigate
CSC	Canadian Surface Combatant
CVBG	Carrier Battle Group
C2	Command and Control
DFAIT	Department of Foreign Affairs and Internal Trade
DFO	Department of Fisheries and Oceans
DND	Department of National Defence
DOD	Department of Defense
DRDC	Defence Research and Development Centre
DRP	Destroyer Replacement Project
DSA	Design Space Analysis
EEZ	Exclusive Economic Zone
EPA	Economic Price Adjustment
FAT	Factory Acceptance Test

FDS	Force Development Scenario
FEA	Foreign Exchange Adjustment
FPS	Force Planning Scenario
FELEX	Frigate Life Extension
FOC	Full Operational Capability
FREMM	Frégate européenne multi-missions (or) Fregata Europea Multi-Missione
GoC	Government of Canada
GSAR	Ground Search and Rescue
HAT	Harbour Acceptance Test
HCM	Halifax Class Modernisation
HUMRO	Humanitarian Relief Operation
IED	Improvised Explosive Device
JSS	Joint Support Ship
JTF	Joint Task Force
KPP	Key Performance Parameter
KUR	Key User Requirement
LOA	Length Overall
LCMS	Life Cycle Management System
MARCOM	Maritime Command
MC	Maritime Component
MCDV	Maritime Coastal Defence Vessel
MCO	Major Combat Operation
MCP	Major Crown Project
MEKO	Mehrzweck-Kombination
MOD	Ministry of Defence
MOE	Measure of Effectiveness
MOP	Measure of Performance
MOOTW	Military Operations Other Than War
MOTS	Military off the Shelf
NATO	North Atlantic Treaty Organization
NDA	National Defence Act
NEO	Non-combatant Evacuation Operation
NGO	Non-Governmental Organization
NORAD	North American Aerospace Defence Command
NRF	NATO Response Force
NSPS	National Shipbuilding Procurement Strategy
OGD	Other Government Department
OGDA	Other Government Department and Agency
ONR	Office of Naval Research
PAG	Project Approval Guide
PCOC	Project Close-out Checklist
PCR	Project Completion Report
PDR	Preliminary Design Review
PMO	Project Management Office
PMP	Project Management Plan
P O&M	Personnel, Operations and Maintenance

PPRA	Project Profile and Risk Assessment
PSO	Peace Support Operation
QFD	Quality Function Deployment
RCMP	Royal Canadian Mounted Police
RMA	Revolution in Military Affairs
ROM	Rough Order of Magnitude
R2P	Responsibility to Protect
SAM	Surface to Air Missile
SAR	Search and Rescue
SAT	Sea Acceptance Test
SCSC	Single-Class Surface Combatant
SLOC	Sea Lines of Communications
SME	Subject Matter Expert
SNMG	Standing NATO Rapid Response Maritime Group
SOR	Statement of Operational Requirement
SP2	Strategic Planning and Prioritization
SRB	Senior Review Board
SRD	System Requirements Document
SSM	Surface to Surface Missile
SSR	Security Sector Reform
SS(ID)	Synopsis Sheet (Identification)
SS(EPA)	Synopsis Sheet (Effective Project Approval)
SS(PPA)	Synopsis Sheet (Preliminary Project Approval)
STFA	Support to Forces Ashore
TRUMP	Tribal Class Update and Modernization Project
TRL	Technology Readiness Level
TSR	Total System Responsibility
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Seas
US	United States
UTE	Unified Trade-off Environment
VLS	Vertical Launching System
V&V	Verification and Validation
WMD	Weapon of Mass Destruction

"If a man will begin with certainties, he shall end in doubts; but if he will be content to begin with doubts, he shall end in certainties."

Sir Francis Bacon
English author, courtier, & philosopher (1561 - 1626)

ABSTRACT

Due to the complex nature of the rapidly evolving and unpredictable global threat environment, the construction of major naval surface combatants capable of effectively responding to all possible missions within the spectrum of conflicts is increasingly difficult. Too often, the result is an elongated procurement process and failed projects due to short-term ambiguous political ambitions, cost-prohibitive operational requirements and technically unfeasible solutions. The procurement process for major naval construction projects should therefore incorporate a strategic planning and prioritization methodology allowing decision-makers to effectively conduct traceable capability trade-offs, early in the design phases.

Using a top-down and bottom-up systems engineering approach, design space analysis transcending several hierarchical levels of abstractions could enable institutional leaders to dynamically identify and evaluate technically feasible and economically viable ship concept designs with a better understanding of the impacts on mission effectiveness, affordability and the risks involved. Such a multidisciplinary approach could potentially optimize the design process and alleviate some of the shortcomings of the procurement process to ensure effective and efficient product development.

INTRODUCTION

BACKGROUND

Canada and its maritime forces face many challenges in a fast changing century characterised by the competition for natural resource demands. Dramatic shifts in integration, information, trade, finance and society, falling broadly under the rubric of globalization, will continue to take place. The world has come a long way in the past two decades since the Cold War and the profound shocks of terrorist attacks. At the same time, continuing tension in the Middle East, social revolutions in North Africa, emerging rival economic powers in the form of Brazil, Russia, India, and China, as well as global financial doldrums pose other problems. In the background, environmental natural disasters and the relentless effects of climate change crossing national boundaries are an ever constant worry.

Canada is not immune to these factors. Unpredictable first and second order effects from outside occurrences will undoubtedly have some influence on Canada's military posture. Government policy, the Department of National Defence's (DND) assessment of risks and vulnerability, and the state of Canada's industrial base to support military needs must therefore be adaptive to an ever changing world. Moreover, the complex and volatile nature of this global threat environment renders the design of major naval surface combatants capable of effectively responding to all possible missions within the spectrum of conflicts increasingly difficult. An integrated and shared understanding of the uncertainties related to the many disciplines and functions involved in the design process must therefore be achieved at inception. The purpose of this study is to provide insights into the strategic planning and prioritization of maritime capabilities for major naval surface combatants during their conceptual design phase.

Canadian Maritime Command (MARCOM) celebrated its centennial anniversary in 2010. The interest in its past and proud traditions of sacrifice, innovation, professionalism and loyalty belied a sense of caution about the role of Canada's maritime forces in performance of its mandated tasks and missions. The Honourable Senator Hugh D. Segal observed: "if our year of celebration is not to generate a mist of nostalgia that obfuscates hard choices, then it is good that we punctuate the celebration and justified rejoicing in accomplishments, past and present, with the odd volley of tough questions that need to be asked, about the future."[1]

What relevance do maritime forces have in the Canadian context and how will they contribute to joint, multinational and inter-agency activities geared toward day-to-day affairs and the conduct of domestic, continental, and international operations when called upon? A good start is the Canada First Defence Strategy (CFDS) released in 2008. This strategy, like other policy statements before it, identified three core roles for the Canadian Forces: defence of Canada, continental and hemispheric security in cooperation with the United States, and maintenance of international peace and security through the projection of leadership abroad in line with Canadian interests and values (see Table 1).[2] The Canadian Forces (CF) and its associated parts constitute the primary instrument for carrying out government's wishes and declared strategy. These three core roles form the geopolitical-level military ambitions in this study, namely the grand strategy of Canada.

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[1] Hugh D. Segal, "Beyond the Celebration: The Next Naval Century" (Ottawa, Conference of Defence Associations Institute (CDAI), 3 March 2010, http://cda-cdai.ca/cdai/uploads/cdai/2009/06/segal-cdai2010.pdf (accessed 1 March 2011).

[2] Canada. Department of National Defence, *Canada First Defence Strategy* (Ottawa, ON: Government of Canada, 2008), 7.

Table 1 - CFDS Core Military Roles

CFDS Military Roles	Requirements and Capabilities
 Defending Canada *Delivering Excellence At Home*	Delivering excellence at home requires the CF to be aware of anything going on in or approaching our territory, deter threats to our security before they reach our shores, and respond to contingencies anywhere in the country. Specifically, it means that the military will maintain the capacity to: • Provide surveillance of Canadian territory and air and maritime approaches; • Maintain search and rescue response capabilities that are able to reach those in distress anywhere in Canada on a 24/7 basis; and • Assist civil authorities in responding to a wide range of threats – from natural disasters to terrorist attacks.
 Defending North America *A Strong and Reliable Partner*	Being a credible partner in the defence of North America requires the CF to: • Conduct daily continental operations; • Carry out bilateral training and exercises with the United States; • Respond to crises; and • Remain interoperable with the US military.
 Contributing to International Peace and Security *Projecting Leadership Abroad*	Projecting leadership abroad will require the CF to have the necessary capabilities to make a meaningful contribution across the full spectrum of international operations, from humanitarian assistance to stabilization operations to combat.

Source: Department of National Defence. *Canada First Defence Strategy*. 2008.

The CFDS envisaged fulfilling these military roles by maintaining its capability and capacity to conduct six core missions within Canada, in North America and globally, at times simultaneously. These six core missions are to conduct daily domestic and continental operations, including in the Arctic and through the North American Aerospace Defence Command (NORAD); support a major international event in Canada (such as the 2010

Olympics); respond to a major terrorist attack; support civilian authorities during a crisis in Canada such as a natural disaster; lead and/or conduct a major international operation for an extended period; and deploy forces in response to crises elsewhere in the world for shorter periods (see Table 2).[3] The CFDS core missions are identified as strategic-level military missions for the purpose of this study.

Table 2 - CFDS Core Military Missions

CFDS Military Missions	Requirements and Capabilities
Conduct daily domestic and continental operations, including in the Arctic and through the North American Aerospace Defence Command (NORAD)	First and foremost, the CF must ensure the security of our citizens and help exercise Canada's sovereignty. Canadians rightly expect their military to be there for them in domestic crises. The Forces must also work closely with federal government partners to ensure the constant monitoring of Canada's territory and air and maritime approaches, including in the Arctic, in order to detect threats to Canadian security as early as possible. Canada fulfills its obligations to NORAD by supplying equipment and personnel. The latest revision of the agreement expands NORAD's mission to include maritime warning.
Support a major international event in Canada (such as the 2010 Olympics)	The Forces must also be available to assist other government departments in addressing such security concerns as over-fishing, organized crime, drug and people smuggling and environmental degradation. As well, the Forces will be prepared to effectively assist other government departments in providing security for major events at home, such as the 2010 Vancouver Olympic Games and the G8 Summit held in Canada that same year.
Support civilian authorities during a crisis in Canada such as a natural disaster	Assist civil authorities in responding to a wide range of threats from natural disasters to terrorist attacks. Earthquakes can overwhelm local capabilities. Our military has been called upon to assist civil authorities in dealing with a number of natural disasters, including floods in Manitoba and Quebec, the ice storm in Eastern Canada, and forest fires in British Columbia. Such disasters will continue to occur, often with devastating consequences, and the citizens affected will expect immediate responses.
Respond to a major terrorist attack	The terrorist attacks of September 11th, 2001 and those carried out since, demonstrate how instability and state failure in distant lands can directly affect our own security and that of our allies. Canada needs a modern, well-trained and well-equipped military with the core capabilities and flexibility required to successfully address both conventional and asymmetric threats, including terrorism, insurgencies and cyber attacks.

[3] Canada. Department of National Defence, *Shaping the Future of the Canadian Forces: A Strategy for 2020* (Ottawa, ON: Government of Canada, June 1999), 10.

CFDS Military Missions	Requirements and Capabilities
Lead and/or conduct a major international operation for an extended period	Providing international leadership is vital if Canada is to continue to be a credible player on the world stage. This will require the CF to have the necessary capabilities to make a meaningful contribution across the full spectrum of international operations, from humanitarian assistance to stabilization operations to combat. Today's deployments are far more dangerous, complex and challenging than in the past, and they require more than a purely military solution.
Deploy forces in response to crises elsewhere in the world for shorter periods	Canada will continue to support and contribute to [the UN and NATO]. In addition, the CF will participate, where circumstances dictate, in missions with like-minded states as a responsible member of the international community. Projecting leadership abroad can take many forms – from taking part in a large international campaign, as Canada is currently doing in Afghanistan, to leading a specific component of a multinational operation, such as a naval task group.

Source: Department of National Defence. *Canada First Defence Strategy*. 2008.

FLEET RECAPITALIZATION IN THE POST COLD WAR ERA

When the Cold War ended in 1989, Canada faced an unpredictable and fragmented world. In this world, conflict, poverty and authoritarianism coexist with relative peace, prosperity and democracy. Moreover, maintaining the essential capabilities of the CF in a time of fiscal restraint, public scrutiny and a lack of clear military threats represents a difficult challenge. To that end, the CFDS is supported by a strategic investment plan based on a commitment to provide predictable funding increases over a 20-year period. This infusion of reliable funding is meant to provide the stability required to conduct long-term planning and meet future requirements with capital equipment renewal.[4] The CFDS promised to revitalize the Canadian fleet by mandating that starting in 2015, fifteen new surface combatants of a common hull design, are to be built to replace the capabilities currently resident in the Iroquois-class destroyers and subsequently the Halifax-class frigates. Table 3 shows an overview of the Halifax-class frigates and Iroquois-class destroyers' capabilities highlighting their main differences.

[4] Canada. Department of National Defence, *Canada First Defence Strategy*, 4.

Table 3 - Halifax-Class Frigates and Iroquois-Class Destroyers Overview

Characteristics	Halifax-class Frigate	Iroquois-class Destroyer
3D Model (by digital artist: Bounding Box)		
Number of ships in service (built)	12 (12)	3 (4)
First Ship Commissioning	29 June 1992	29 July 1972
Last Ship Commissioning	28 September 1996	16 December 1972
Displacement	4,770 tonne	5,300 tonne
Length Overall (LOA)	134.7 metre	121.4 metre
Beam	16.4 metre	15.2 metre
Draught	4.9 metre	4.7 metre
Speed	29 kn (53.71 km/h)	27 kn (50.0 km/h)
Range	9,500 nm at 13 kn (17,594 km) 3,930 nm at 18 kn (7,278 km)	4,500 nm at 15 kn (8,300 km)
Complement	198 (17 officers) + 17 (8 officers) aircrew	255 (23 officers) + 30 (9 officers) aircrew
Main Gun	1 x Bofors 57 mm/70 Mk 2	1 x OTO Melara 76 mm/62
Surface to Air Missile (SAM)	Short Range (self-defence)	Medium and Long Range (AAD)
Surface to Surface Missile (SSM)	Yes	No
Vertical Launching System (VLS) Cells	16	29
3D Multi Function Radar	Yes	No
Towed Array Sonar	Yes	No
Maritime Helicopter	1 x CH-124A Sea King	2 x CH-124A Sea King
Flight Deck and Hangar	Flight Deck with single hangar	Flight Deck with double hangar

Source: *Jane's Fighting Ships 2010-2011*, edited by Stephen Saunders. 2010.

The Iroquois-class destroyers, also called Tribal-class destroyers, are Command and Control (C2) vessels which were built in the early 1970s for Cold War long-range anti-submarine warfare (ASW). They underwent the Tribal-class update and modernization project (TRUMP) in

the early 1990s which re-purposed them as area air defence (AAD) destroyers.[5] Their ASW role was transferred to the Halifax-class frigates, also called the Canadian Patrol Frigates (CPF), which were also designed for Cold War open ocean environment threats including anti-surface warfare (ASuW). These frigates are undergoing the Halifax-class modernisation (HCM) frigate life extension (FELEX) program from 2010 to 2017 to, amongst other things, integrate new C2 capabilities and extend the ship's life to 2030.[6]

Both the Iroquois-class destroyers and Halifax-class frigates were designed and built for Cold War era threats. But the current post 9/11 global security environment and the rapid proliferation of technology engendered threats that are faster, stealthier, networked, and increasingly engaged in littoral waters. These new types of threats challenge the effectiveness of sensors and weapons systems beyond their original intent.[7] The US Deputy Secretary of Defense, William J. Lynn, III highlighted three of these challenges during his visit at a Conference for Defence Associations Institute (CDAI) in Ottawa on 14 June 2010. He remarked that the first change in the nature of warfare is that lethality no longer tracks closely with the threat spectrum. Indeed, rogue states, terrorist organisations and insurgents aspire to possess weapons of mass destruction (WMD), sophisticated improvised explosive devices (IEDs), or world-class cyber capabilities traditionally associated with powerful military nations. The second change is the increasing duration of conflict beyond the initial "shock and awe" of perceived rapid dominance by overwhelming power and spectacular display of brute force. He

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[5] Tony Thatcher, "The Story of the Tribal Class Update and Modernization Project (TRUMP)," *Canadian Naval Defence Industrial Base (CANDIB) Research Project* (2009), http://www.cntha.ca/ (accessed 4 February 2011).

[6] Canada. Department of National Defence, "Halifax-Class Modernization (HCM) / Frigate Life Extension (FELEX)," *Canadian Navy News* (2011), www.navy.forces.gc.ca/cms (accessed 4 February 2011).

[7] Warnings that operations by large destroyers and frigates inshore are impractical and unadvisable have been in the professional literature for years. See Ken Hansen, "The Superior-Simple Ship Fleet Construct," *Canadian Naval Review* 3, no. 2 (Summer 2007), 4-7.

noted that the Iraq and Afghanistan wars have now lasted longer than the US participation in World War I and World War II combined. The third and most prominent change in the global security environment is that the practice of war has moved toward asymmetric conflict whereby guerrilla tactics are exploited more effectively to negate conventional superiority or control the timing of conflict.[8]

In addition to dealing with these challenges, MARCOM must also meet the political and public expectations to assist other government departments (OGD) and non-governmental organizations (NGO) in ways which had not been envisaged when the Iroquois-class destroyers and Halifax-class frigates were first designed. As suggested by Figure 1, non-combat operations including military operations other than war (MOOTW) supporting the CFDS preponderance for domestic operations, may occupy a larger portion of the spectrum of conflict. Of note, MOOTW usually accentuates the need for flexible crew size and skills set whereas combat operations are heavily predicated on specialized equipment. Indeed, Canadian naval doctrine suggests that "success in modern warfare against a well-equipped enemy requires superior intelligence, a quicker decision-making cycle, flexible and agile forces, and systems that can deliver selective firepower at great range."[9]

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[8] William Lynn, "Remarks by US Deputy Secretary of Defense William J. Lynn, III at an Event at the Fairmont Chateau Laurier Hotel in Ottawa on June 14 before the Conference of Defence Associations Institute" (Ottawa, Conference of Defence Associations Institute (CDAI), 14 June 2010, , http://cda-cdai.ca/cdai/publications/depseclynn (accessed 1 March 2011).

[9] Canadian Forces College, *Naval Doctrine Manual* (Toronto, ON: Canadian Forces College, 2006), C-4.

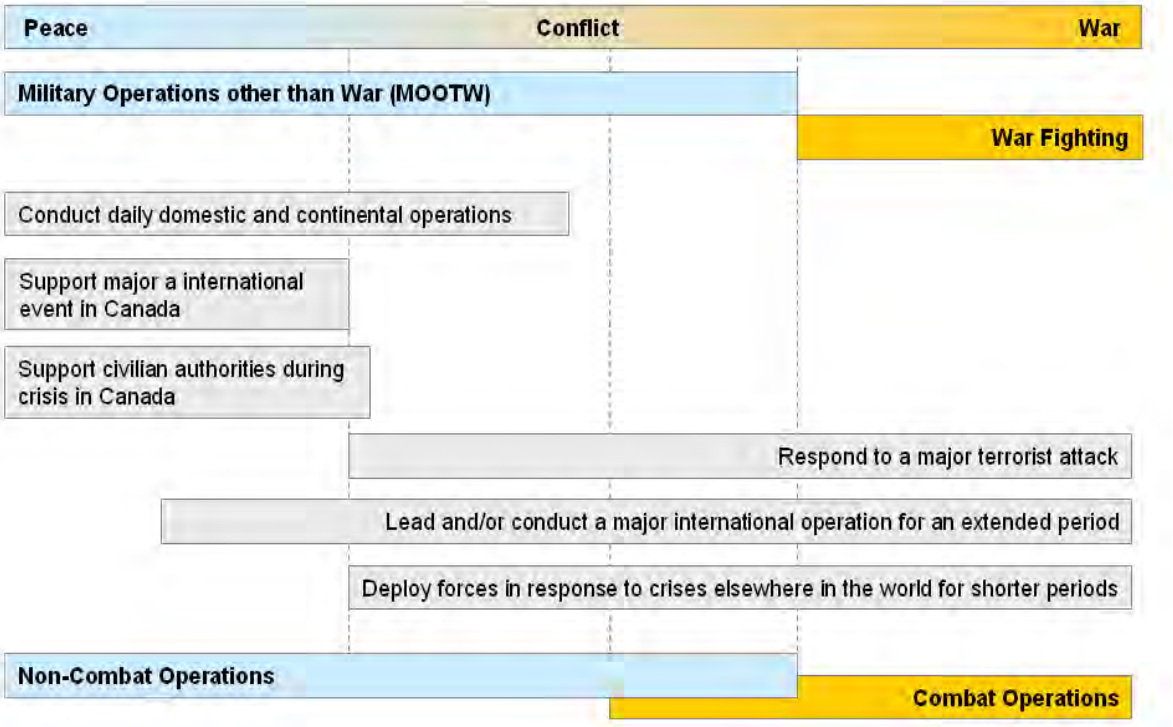

Figure 1 - CFDS Military Missions in Spectrum of Conflicts

Source: Adapted from Department of National Defence. *B-GG-005-004/AF-023 Civil-Military Cooperation in Peace, Emergencies, Crisis and War*. 1999.

PROBLEM DEFINITION

With only a few statements, the 2008 Canada First Defence Strategy confronts DND with the project management "triple threat" of scope, time and cost.[10] A naval major crown project (MCP) is identified which should link and contribute the maritime domain capabilities to the mandated CFDS military roles and missions. But what are the current Iroquois-class and Halifax-class capabilities to be retained? What are the future and relevant naval missions to be preparing for? Can a common hull, single class surface combatant, effectively respond to all possible missions within the spectrum of conflicts? Is the allocated budget sufficient to cover the

[10] Project Management Institute (PMI), *A Guide to the Project Management Body of Knowledge (PMBOK Guide)*, 3rd ed. (Evanston, IL: EIS Digital Publishing, 2004).

acquisition of fifteen state-of-the-art destroyer-frigate type ships? Is the Canadian naval shipbuilding industry capable or willing to accommodate for this demand, as well as the other governmental and private industry projects? While these questions are examined in this study, the primary concern remains that Canada's procurement process for naval MCPs should be improved such that institutional leaders can successfully satisfy political aspirations whilst responding to operational requirements, real and perceived, for the next 30 years.

A project is deemed to be an MCP when its estimated cost exceeds $100 million and when the Treasury Board assesses the project as high risk or high public visibility.[11] With that level of financial outlook, every decision matters and may have long-term repercussions in the political and regional economic realms. Too often, however, the result is an elongated procurement process and failed projects due to vague political ambitions, lack of military strategic focus, cost-prohibitive operational requirements and technically unfeasible solutions.

Although succumbing to a plethora of circumstantial conditions beyond the control of the project management office (PMO), the reset of the Joint Support Ship (JSS) project in 2009 is considered. Originating from the 1992 Afloat Logistics and Sealift Capability (ALSC) project,[12] the JSS project was initially announced in 2004 to replace the core capabilities of the Protecteur-class auxiliary oiler replenishment (AOR) ships. After almost two decades of design explorations, bureaucratic and contractual negotiations, and an exorbitant amount of tax money squandered, a contract for construction has not yet been signed and proposed entry into service continues to be postponed. The delays in the JSS acquisition raised several questions and cast

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[11] Canada. Department of National Defence, *Project Approval Guide* (Ottawa, ON: VCDS Director Defence Programme Coordination, 2009), 4-1c.

[12] Bruce T. Irvine, "Afloat Logistics and Sealift Capability for the Canadian Navy," *Canadian Defence Quarterly* (Summer 1997), 14-19, http://centreforforeignpolicystudies.dal.ca/cdq/Irvine%20Summer%201997.PDF (accessed 4 March 2011).

the shadow of doubt on the government's procurement process. Sharon Hobson (2010) asked some key questions of interest to the industry:

> What naval capabilities does the government want and why? Where does the JSS fit into this vision? The ships that are now being acquired are significantly different from the previous plans, and there is no government documentation to account for this change… Or was the JSS decision made solely on the basis of cost? And if that is so, what was the trade-off in terms of security and influence that made such a decision acceptable?[13]

Could the same fate await the Canadian Surface Combatant (CSC) project, which replaced the Destroyer Replacement Project (DRP), which replaced the Single-Class Surface Combatant (SCSC) project, which has apparently replaced the Command-and-Control and Area Air-Defence Capability Replacement (CADRE) project initiated back in 1994 to examine the replacement of the C2 and Task Group AAD capabilities provided by the ageing Iroquois-class destroyers?[14]

To that end, Christian Johansson (2011) explains that while there will always be a major component of inherent risk, ambiguity and uncertainty in any exploratory design activity, it is increasingly important to efficiently and explicitly identify and understand such ambiguities early in the procurement and design processes. The sources of uncertainty are many and include considerations related to user needs, technology, production, and market conditions.[15] The aim is not to completely eliminate risk and uncertainties, but to increase collective awareness so that decision-makers can move forward with a better understanding of the capability trade-offs resulting of well-founded conscious choices rather than implicit and less sophisticated

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[13] Sharon Hobson, "Plain Talk: JSS Adrift in a Strategic Black Hole," *Canadian Naval Review* 6, no. 3 (Fall 2010), 35-36, http://naval.review.cfps.dal.ca/pdf/vol6num3_fall2010_excerpt.pdf (accessed 31 March 2011).

[14] Michael U. Burke, "The Command/Control and Air Defence Replacement (CADRE) Project," *Canadian Defence Quarterly* 27, no. 4 (Summer 1998), 25-28, http://centreforforeignpolicystudies.dal.ca/cdq/Burke%20Summer%201998.PDF (accessed 4 March 2011).

[15] Christian Johansson and others, "Knowledge Maturity as a Means to Support Decision Making during Product-Service Systems Development Projects in the Aerospace Sector," *Project Management Journal* 42, no. 2 (March 2011), 32-50.

assumptions. Indeed, it is better to fail early and often than to haphazardly commit considerable capital investment which can neither be returned nor validated for "fitness of purpose" until the ship is in service.[16]

The historical overview of the Canadian naval shipbuilding industry offered in Chapter one highlights the shortcomings of both the current DND procurement process and current naval ship design methodology. Indeed, history has consistently shown that the Canadian shipbuilding industry for large high-value vessels is incapable of competing internationally and is unsustainable domestically without government contracts.[17] If the national policy is to retain warship production within Canada, a holistic and coherent procurement process is required to alleviate the constraints affecting the design capabilities of both the DND and the industry teams, the manufacturing facilities and labour skills, coordination of commercial and contractual issues across suppliers and regions, and long-term continuity of employment.[18] Unfortunately, the current procurement process for naval MCPs can take up to 10 to 15 years to complete without the verification and validation that the government has used accurate cost estimates or developed appropriate technical specifications in compliance and conformity with operational requirements. This predicament is exacerbated by an extemporized naval ship design methodology, whereby selection of design concepts is too often guided primarily by experience, design lanes, rules-of-thumb, preference and imagination.[19]

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[16] Ibid.

[17] Ty Curran, "The Single Shipbuilding Entity Model in Canadian Naval Procurement: A Discussion Paper on Naval Contracts in Canada," *Journal of Military & Strategic Studies* 8, no. 3 (Spring 2006), http://www.jmss.org/jmss/index.php/jmss/article/view/135/151 (accessed 1 March 2011).

[18] UK Ministry of Defence (MOD), *Warship Engineering Management Guide, MAP 01-020*, 1st ed. (Bristol, UK: Defence Equipment & Support, Sea -Surface Ship Division, 2007), 16.

[19] Alan Brown and Mark Thomas, "Reengineering the Naval Ship Concept Design Process" American Society of Naval Engineers (ASNE), September 1998), http://www.aoe.vt.edu/~brown/Papers/ASNE98Reengineering.pdf (accessed 21 January 2011).

Chapter two offers a possible solution to optimising the procurement and design processes in the guise of a strategic planning and prioritization (SP2) process potentially allowing decision-makers to rapidly conduct traceable cost-capability trades early in the design phases. The objective is to expressly link geopolitical-level aspirations to strategic-level military missions, then to operational-level activities and functions, and next to tactical-level ship-level capabilities. Using a top-down and bottom-up systems engineering approach, design space analysis transcending these hierarchical levels of abstractions could enable institutional leaders to dynamically identify and evaluate technically feasible and economically viable ship concept designs with a better level of fidelity. This methodology may also produce a robust analysis of multiple ship configurations while providing a defensible selection process taking into account the multiple risks involved.

Chapter three explores the usefulness of the SP2 process by examining several scenarios including whether Canada can afford to procure 15 ships of a single class of "reconfigurable" multi-purpose surface combatant. In order to reduce the total cost of ownership of the surface fleet and leverage economies in scale and scope, any design aspires to an upgradeable high-performance surface combatant with top-level expeditionary capabilities in all warfare domains as well as all other capabilities dedicated to sea control and sovereignty, integrated in one common platform. The alternative option considered is that the "transformed" Canadian navy fleet be composed of a balanced mix of affordable destroyers, frigates, corvettes and offshore patrol vessels (OPVs).

CHAPTER 1 – SHIP DESIGN AND PROCUREMENT PROCESS

CANADIAN NAVAL SHIPBUILDING

The impasse plaguing Canada's capability to procure major surface combatants has roots in the cyclical atrophy of the national naval shipbuilding industry since World War II. Appendix 1 shows the laid down, launching and commissioning dates for Canadian destroyers and frigates from 1945 to 2010, including the respective building shipyards. This data is summarised in Table 4 and graphically illustrated in Figure 2 which clearly show three construction surges. First, the post World War II golden era saw the serial construction of twenty St. Laurent, Restigouche, Mackenzie and Annapolis-class destroyer-escorts from 1950 to 1964. Four Iroquois-class destroyers followed during the Cold War in the peak years from 1969 to 1972; and, more recently, the twelve Halifax-class frigates were procured from 1987 to 1996.

For the destroyer-escorts and Iroquois-class destroyers, the navy exercised the role of design authority and relied primarily upon in-house capabilities to manage the construction contracts with commercial shipyards. For the Halifax-class frigates, total system responsibility (TSR) was vested in the prime contractor, Saint John Shipbuilding Limited, though the CPF PMO retained a staff of approximately 200 people to oversee the project.[20]

[20] Ken Bowering, "Military / Naval Procurement in Canada: A Flawed Process," *CDAI General Sir Arthur Currie Papers* (19 November 2008, 2008), http://www.cda-cdai.ca/cdai/uploads/cdai/2008/12/currie_1-08bowering.pdf (accessed 1 March 2011).

Table 4 - Canadian Destroyers and Frigates Shipbuilding 1945-2010

Period	Ship Type	Ship Class	Shipyard
1950-1964	Destroyer-Escort	(7) St. Laurent (1950-1957) (7) Restigouche (1953-1959) (4) Mackenzie (1958-1963) (2) Annapolis (1960-1964)	Canadian Vickers Ltd., Montreal QC Marine Industries Ltd., Sorel QC Davie Shipbuilding Ltd., Lauzon QC Halifax Shipyard Ltd., Halifax NS Burrard Dry Dock Ltd., Vancouver, BC Victoria Machinery Depot Ltd., Victoria BC
1969-1972	Destroyer	(4) Iroquois	Marine Industries Ltd., Sorel QC Davie Shipbuilding Ltd., Lauzon QC
1987-1996	Frigate	(12) Halifax	Saint John Shipbuilding Ltd., Saint John, NB MIL-Davie Shipbuilding Ltd., Lauzon QC

Source: Canadian Navy

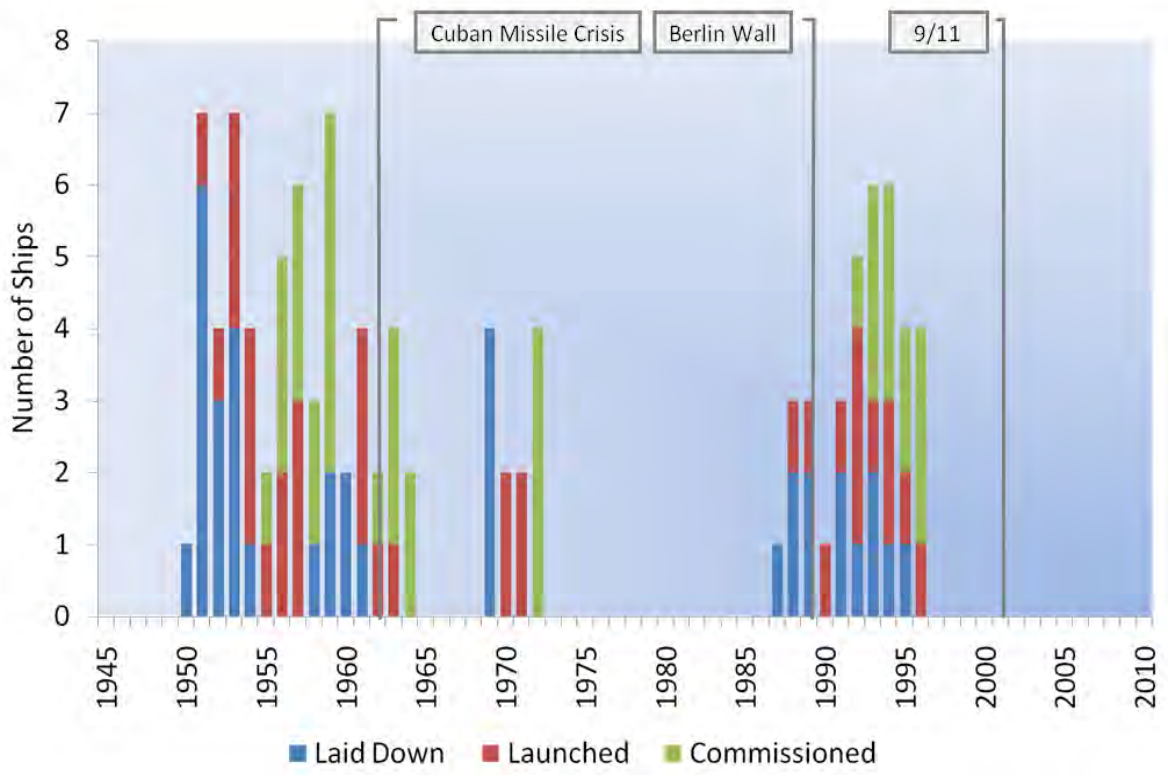

Figure 2 - Canadian Destroyers and Frigates Shipbuilding 1945-2010

In the years since the CPF project, the defence team suffered a generational gap of non-activity in the discipline of major surface combatant design accentuated by unprecedented CF wide downsizing. Rationalizing in DND during the 1990s led to early retirement of highly experienced systems engineers, naval architects and constructors, who once led conceptual studies, managed design trade-offs, and oversaw construction. Remaining and new experience has now been relegated to life-cycle support, mid-life refit projects, or smaller scale constructions such as the Orca-class patrol vessels and the Kingston-class maritime coastal defence vessels (MCDVs). The eight Orca-class patrol vessels were loosely based on the Australian-designed Pacific-class patrol boat and were constructed by Victoria Shipyards in Esquimalt, BC between 2004 and 2008. The twelve Kingston-class MCDVs were built by Halifax Shipyard Ltd., in Halifax NS between 1994 and 1999. But even then, the large engineering and construction firm SNC-Lavalin Ltd., assumed TSR as the design agent and prime contractor.[21]

Without any governmental major contracts or other incentives such as subsidies and low interest loans, the shipyards and associated industries struggled to maintain ship design and building capabilities in anticipation for future naval projects. Construction of warships involves the use of exotic materials, the installation of large amounts of high-value, sensitive equipment, the requirement for highly skilled and specialized workers, and the satisfaction of more exacting military standards.[22] Such high overhead could not be sustained by insufficient commercial domestic demand, and the foreign over-capacity created by major players such as South Korea, Japan and Norway who rendered the global market largely monopolized by these industrial

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[21] Ibid.

[22] John Birkler and others, *Difference between Military and Commercial Shipbuilding: Implications for the United Kingdom's Ministry of Defence* (Santa Monica, CA: RAND Europe, 2005), 111, http://www.rand.org/pubs/monographs/2005/RAND_MG236.pdf (accessed 31 March 2011).

leaders. Furthermore, the American Jones Act written in 1920 still requires that all water transportation of goods between US ports be on US built, owned, crewed and operated ships. The shipyard capabilities developed during the CPF and TRUMP projects thus redirected their effort in ship repair activity and niche markets such as tugboats and the offshore oil and gas industry.[23] For these reasons, a national program to support the revival of the industry, maintain a strategic commodity and safeguard the significant investment in infrastructure and personnel is necessary.[24]

Supporting this view is the well documented postulation that major mid-life modernization projects such as TRUMP and HCM/FELEX may not be the most cost-effective option for destroyer and frigate type ships. Instead of building ships with a design life of 30 to 40 years, it is suggested to operate them for at most 15 years and resell them to a lesser tier navy before obsolescence. A continuous build at a rate of one or two ships per year would suffice to maintain a sufficient number of ships in service and ensure Canada always has relatively modern ships.[25]

To that end, the concept of a continuous built program was endorsed by the federal government in June 2010 with the National Shipbuilding Procurement Strategy (NSPS). The NSPS acknowledges that the "Canadian shipyards lack modern industrial infrastructure, design capacity, well-developed marine supply lines, world class productivity, and an assured cost-effective skilled labour to build large complex ships."[26] In an attempt to remedy the situation, the NSPS mandate is to help build and maintain an effective federal fleet for maritime security

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[23] Canada. Department of National Defence, *Project Charter: National Shipbuilding Procurement Strategy Office* (Ottawa, ON: National Shipbuilding Procurement Strategy Office, September 2008), 6.

[24] Curran, *The Single Shipbuilding Entity Model in Canadian Naval Procurement: A Discussion Paper on Naval Contracts in Canada*, 1 March 2011.

[25] Bowering, *Military / Naval Procurement in Canada: A Flawed Process*

[26] Canada. Department of National Defence, *Project Charter: National Shipbuilding Procurement Strategy Office*, 6.

and services while maximizing economic benefits across Canada.[27] One shipyard will be selected to build combat vessels enabling the procurement of the CSC and Arctic/Offshore Patrol Ships (AOPS). Another competitively selected shipyard will build non-combat vessels, such as the JSS.[28] The NSPS approach relies on collaboration between DND, Public Works and Government Services Canada, the Department of Fisheries and Oceans (DFO), and Industry Canada to maintain a thriving and progressive marine and shipbuilding sectors, create long-term regional employment and exploit new technology.

A significant collateral incentive of the NSPS could be the reviving of the design authority role within DND and the streamlining of a cumbersome procurement process. But given the complexity of design and construction, the very high price tag, and the number of departmental stakeholders involved, warship procurement will arguably remain among the most complex and expensive procurement activities that can be undertaken by government. Concurrently, the Honourable Senator Hugh D. Segal warned the navy:

> When I hear civil servants address naval procurement requirements that are real and pressing with multi-month and multi-year shipbuilding strategies and elaborate discussions and consultations, I can see an ambush of the highest and most compelling sophistication taking shape. And I can hear the hooves of the four horses of the fiscal eclipse [Treasury Board, Finance Canada, Privy Council Office and Supply and Services]. Some no doubt involved in this, from industry, from the Cabinet are sincere and well-meaning. I do not doubt that. But remember, in the battle of Ottawa, delay is victory for the four horsemen, not for the forces of light and deployable military naval capacity.[29]

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[27] Canada. Department of National Defence, "Canada's National Shipbuilding Procurement Strategy," National Defence and the Canadian Forces, http://www.forces.gc.ca/site/pri/2/ship-navale-eng.asp (accessed 4 March 2011,

[28] Canada. Department of National Defence, "The Department of National Defence and the Government of Canada's National Shipbuilding Procurement Strategy," National Defence and the Canadian Forces News Room, http://www.forces.gc.ca/site/news-nouvelles/news-nouvelles-eng.asp?cat=00&id=3401 (accessed 4 March 2011,

[29] Segal, *Beyond the Celebration: The Next Naval Century*, 12.

PROCUREMENT PROCESS

The current government procurement process is adapted to MCPs of a shorter developmental timeline and of significantly less complexity than that of warships. Many projects are of the commercial-off-the-shelf (COTS) or even military-off-the-shelf (MOTS) nature such as the army's family of land combat systems' vehicles. Although COTS and MOTS type procurements will always require a level of configuration tailoring, they nevertheless have the advantage that scope and cost uncertainties are minimised as the system's technology readiness level (TRL) is more mature. Alas, as explained in the previous section, there are no COTS or MOTS solutions in the Canadian naval shipbuilding industry, a situation further compounded by a severe lack of corporate memory and design experience within DND.

The DND Project Approval Guide (PAG) describes in detail the procurement process in gaining Ministerial Departmental Approval to allocate funding. As well, the PAG covers granting Expenditure Authority by Treasury Board to expend financial resources toward acquisition and delivery of a capital program.[30] Project management activities are elicited to plan, organize, implement and control specific objectives within such parameters as scope, cost, schedule, performance and risk. The procurement process evolves through five successive phases, one leading to the other via decision documents called synopsis sheets. These phases are identification; options analysis; definition; implementation; and close-out. Appendix 2 shows the activities for each of these phases whilst the key activities are summarised in Table 5.

[30] Canada. Department of National Defence, *Project Approval Guide*

Table 5 – Key Activities in Capital Project Approval Phases

Phase	Key Activities
Identification	• Identification of potential solutions in broad terms. • Preparation of a rough order of magnitude (ROM) cost estimate for planning purposes. • Preparation of an initial risk assessment. • Initiation of a Statement of Operational Requirement (SOR).
Option Analysis	• Conducting studies to produce a costed options analysis which examines the Capital requirements and the resulting Personnel, Operations and Maintenance (P, O&M) resource impact. • Conducting studies to produce an indicative total cost estimate of the preferred option. • Refinement of the SOR.
Definition	• Conducting studies to produce a final SOR. • Conducting studies to produce a substantive estimate of the total cost of the preferred option based on detailed system and component designs. • Conducting studies to produce a substantive estimate of the transition and recurring P, O&M costs associated with implementation of the project.
Implementation	• Final shifting of project leadership from sponsoring organization to the implementing organization. • Attain Full Operational Capability (FOC) indicating that project implementation has satisfactorily met specified performance documented in the SOR.
Close Out	• Completing the Project Close-out Checklist (PCOC). • Closing down the project office.

Source: Department of National Defence. *Project Approval Guide*. 2009.

Early in the identification phase, project staffs are asked to identify potential solutions in broad terms, prepare a rough order of magnitude (ROM) cost estimate for planning purposes, and produce an initial risk assessment. Despite best efforts, project staffs for naval MCPs are unlikely to account for the interoperability and unpredictability of all the systems and factors involved in the larger system-of-systems context. Some constraints related to the ship design methodology are examined in the next section. Other contractual and intangible risks include material and workmanship, design warranty, limitation of liability, shipbuilder's insurance, workforce disruption, liquidated damages, excusable delays, economic price adjustment (EPA) and foreign exchange adjustment (FEA). There are simply too many uncertainties for any

accurate cost estimate to survive the long duration of the procurement process in an unstable market environment aggravated by worldwide commodity volatilities. Nevertheless, as illustrated in Figure 3, a premature ROM budget based on preliminary information and assumptions rather than on established facts is committed for the planning of the total anticipated capital project cost before even entering the option analysis phase.

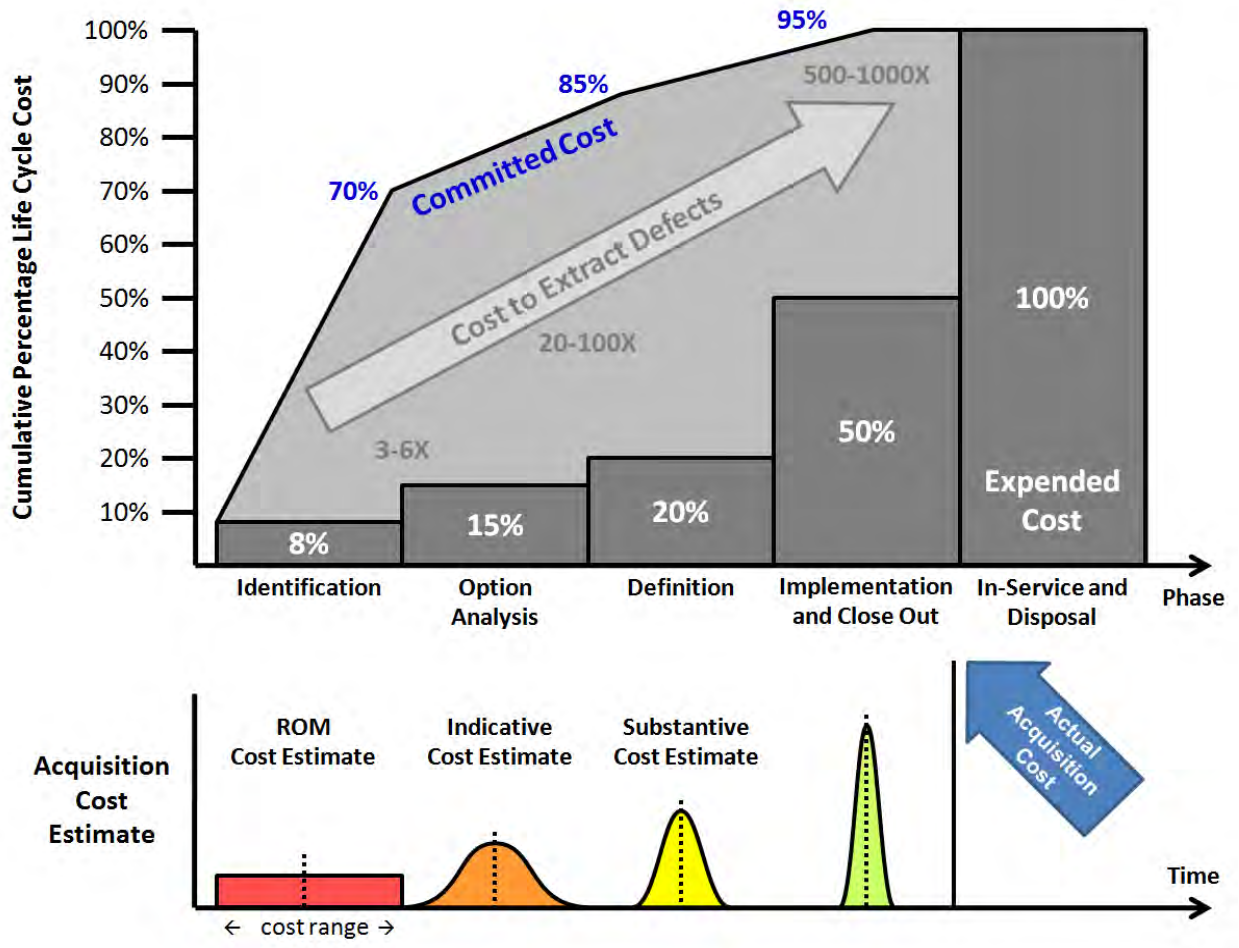

Figure 3 - Cost Estimation Commitment and Fidelity

Source: Adapted from INCOSE and NPS 5th Annual Acquisition Research Symposium, Panel 14 – Issues in Cost Estimating for US Shipbuilding, 15 May 2008

During the option analysis phase, studies are conducted to produce an indicative total cost estimate of the preferred option. An indicative cost is defined as a low quality, order of magnitude estimate that is insufficiently accurate for Treasury Board approval. During the definition phase, further studies are conducted to produce a substantive estimate of the total cost of the preferred option based on detailed system and component design and taking into account all project objectives and deliverables. A substantive cost estimate is defined as one of sufficiently high quality and reliability for Treasury Board approval. But the budget was already committed earlier during the identification phase based on a ROM for a potential solution which was itself based a preliminary Statement of Operational Requirements (SOR) describing the mandated performance objectives in qualitative operational terms.[31]

During the option analysis and definition phases, the SOR is refined but is subjected to the caprices of several rotations of directors of maritime requirements who sometimes have opposing views on the missions' terms of references. As the SOR changes, so should the System Requirements Document (SRD) which serves as the technical translation of the SOR, and the benchmark to validate the system-centric solution and contract specifications.[32] Systems engineers and naval architects usually struggle with operators to adjust the SRD to the SOR. Consequently, development of ship concept designs may eventually lose traceability and conformity with the SOR and the ship's Concept of Operations (ConOPS). A common language must exist between technical staffs, operators and senior managers in order to facilitate the

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[31] Canada. Treasury Board Canada, *Treasury Board Manual - Information and Administrative Management Component, Capital Plans, Projects and Procurement* (Ottawa, ON: Government of Canada, June 1994).

[32] UK Ministry of Defence (MOD), "System Requirements Document (SRD) Principles," in *Policy, Information and Guidance on the Requirements and Acceptance Aspects of UK MOD Defence Acquisition*, ed. Acquisition Operating Framework (AOF), 1.0.3 ed. (Norwich, UK: Her Majesty's Stationery Office's (HMSO), October 2010), http://www.aof.mod.uk/aofcontent/tactical/randa/content/srdprinciples.htm (accessed 20 January 2011).

drafting of capability-based requirements against which the industry can deliver cost-effective bids and compliant solutions.[33]

The current procurement process carries a high level of corporate inertia which does not allow flexibility to dynamically adjust the scope and progressively refine the budget as information becomes available. By the time the knowledge base is established in later stages, the major decisions are already made, capital has already been committed, and it is therefore more costly and time-consuming to remedy any shortcomings, if at all.[34] Great flexibility must thus exist in the early phases of identification and option analysis so that senior management can readily provide educated and traceable cost-capability trades with better known impacts on mission capability effectiveness, affordability and risk.

More importantly, the procurement process is inextricably intertwined with the engineering design process, regardless of the viewpoints as shown in Table 6. One cannot attempt to solve a problem in one aspect without considering the integrated correlation between both. As just elucidated with the procurement process, the prevailing issue is that both processes suffer from the design process paradox whereby as more knowledge and information is gained on the design problem over time, the less freedom and opportunity to influence the design scope, budget and schedule remains.[35] The most important decisions are made and the most amount of funding is committed when knowledge is the least, conversely, the least freedom to influence a design and the least amount of money can be allocated when knowledge is the most. This predicament is further exacerbated by the use of an antiquated ship design methodology.

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[33] Bowering, *Military / Naval Procurement in Canada: A Flawed Process*

[34] Johansson and others, *Knowledge Maturity as a Means to Support Decision Making during Product-Service Systems Development Projects in the Aerospace Sector*, 33.

[35] David G. Ullman, *The Mechanical Design Process*, 3rd ed. (New York, NY: McGraw-Hill, 2002), 432.

Table 6 - Comparison of Engineering Design Process Models

Models	Establishing a need phase	Analysis of task phase	Conceptual design phase	Embodiment design phase	Detailed design phase	Implementation phase
Booz et al. (1967)	X	New product strategy development	Idea generation / Screening & evaluation	Business analysis / Development	Testing	Commercialisation
Archer (1968)	X	Programming / data collection	Analysis / Synthesis	Development	Communication	X
Svensson (1974)	Need	X	Concepts	Verification / Decisions	X	Manufacture
Wilson (1980)	Societal need	Recognize & formalize / FR's & constraints	Ideate and create	Analyze and/or test	Product, prototype, process	X
Urban and Hauser (1980)	Opportunity identification	Design		Testing		Introduction (launch) / Life cycle management
VDI-2222 (1982)	X	Planning	Conceptual design	Embodiment design	Detail design	X
Hubka and Eder (1982)	X	X	Conceptual design	Lay-out design	Detail design	X
Crawford (1984)	X	Strategic planning	Concept generation	Pre-technical evaluation	Technical development	Commercialisation
Pahl and Beitz (1984)	Task	Clarification of task	Conceptual design	Embodiment design	Detailed design	X
French (1985)	Need	Analysis of problem	Conceptual design	Embodiment of schemes	Detailing	X
Ray (1985)	Recognise problem	Exploration of problem / Define problem	Search for alternative proposals	Predict outcome / Test for feasible alternatives	Judge feasible alternatives / Specify solution	Implement
Cooper (1986)	Ideation	Preliminary investigation	Detailed investigation	Development / Testing & Validation	X	Full production & market launch
Andreasen and Hein (1987)	Recognition of need	Investigation of need	Product principle	Product design	Production preparation	Execution
Pugh (1991)	Market	Specification	Concept design		Detail design	Manufacture / Sell
Hales (1993)	Idea, need, proposal, brief	Task clarification	Conceptual design	Embodiment design	Detail design	X
Baxter (1995)	Assess innovation opportunity	Possible products	Possible concepts	Possible embodiments	Possible details	New product
Ulrich and Eppinger (1995)	X	Strategic planning	Concept development	System-level design	Detail design	Testing & refinement / Production ramp-up
Ullman (1997)	Identify needs / Plan for the design process	Develop engineering specifications	Develop concept	Develop product		X
BS7000 (1997)	Concept / Feasibility		Implementation (or realisation)			Termination
Black (1999)	Brief/concept	Review of 'state of the art'	Synthesis / Inspiration	Experimentation / Analysis / reflect	Synthesis / Decisions to constraints / Output	X
Cross (2000)	X	Exploration	Generation	Evaluation	Communication	X
Design Council (2006)	Discover	Define	Develop		Deliver	X
Industrial Innovation Process 2006	Mission statement	Market research	Ideas phase	Concept phase	Feasibility Phase	Pre production

Source: Howard, T. J., S. J. Culley, and E. Dekonick. "Describing the Creative Design Process by the Integration of Engineering Design and Cognitive Psychology Literature." *Design Studies* 29, no. 2 (2008): 160-180.

SHIP DESIGN METHODOLOGY

Traditional ship design methodologies tend to be sequential in nature implying that educated guesses are initially postulated then analysed and modified, in a sequential series of steps, as information becomes available. Figure 4 illustrates such a design spiral approach wherein a series of design tasks are performed, each dependent on initial assumptions, using data generated by a previous task and, in turn, generating additional information for a following task with the aim to eventually converge on a balanced solution after a few iterations.[36] The first iteration of the design spiral process is often called the concept design phase which principal objective is to clarify the SOR key requirements and balance these required capabilities with affordability and risk. Many concept designs may be performed to identify significant cost and design drivers and examine technology gaps to focus research.[37]

[36] UK Ministry of Defence (MOD), *Warship Engineering Management Guide, MAP 01-020*, 4.

[37] Peter A. Gale, "The Ship Design Process," in *Ship Design and Construction - Volume 1*, ed. Thomas Lamb (Jersey City, NJ: The Society of Naval Architects and Marine Engineers, 2003), 5-1 - 5-39.

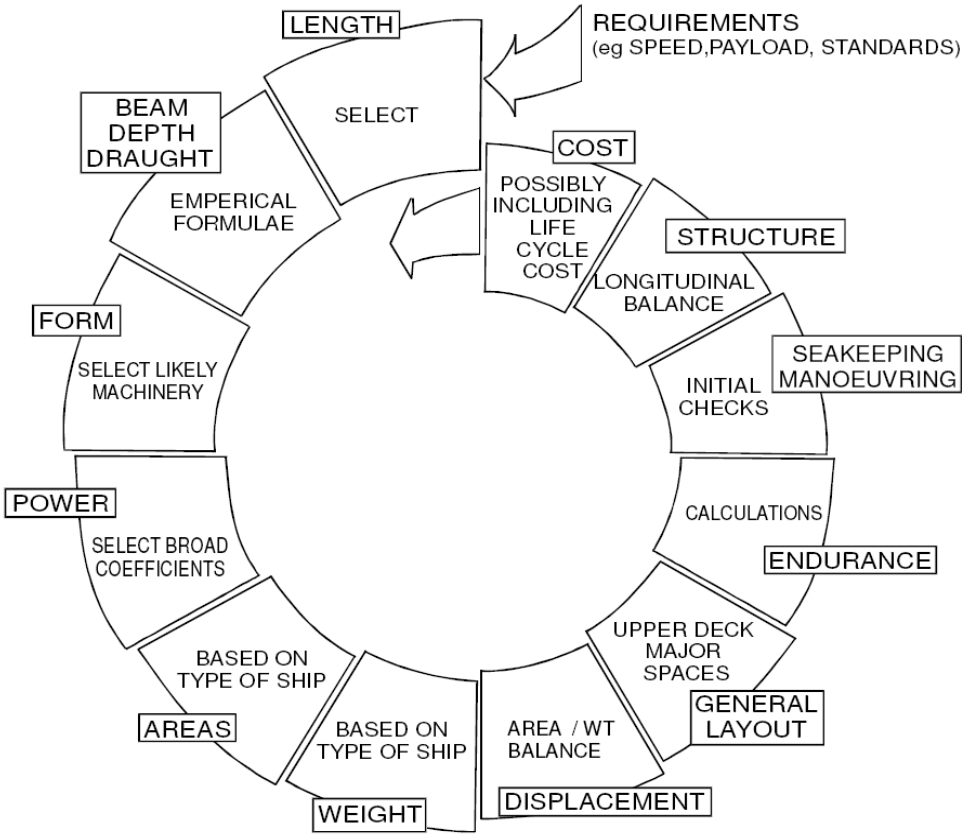

Figure 4 - Traditional Ship Design Spiral

Source: UK Ministry of Defence. *Warship Engineering Management Guide*. 2007.

Optimization using this method is time-consuming because computational sequencing limits the number of degrees of freedom that can be manipulated simultaneously to better understand the interdependencies between factors such design parameters, technology selections, and mission success. Military ship takes longer to design than commercial ships because of their extremely high equipment density, the complexity and multi-functionality of large number of sophisticated systems involved, and the desire to at least match the current state of the art.[38] The reality is that ship design is a networked system-of-systems multidisciplinary process whereby a

[38] Birkler and others, *Difference between Military and Commercial Shipbuilding: Implications for the United Kingdom's Ministry of Defence*, 111.

decision on one aspect of the design will have simultaneous and latter second, third and fourth (etc.) order effects on other aspects of the design as illustrated in Figure 5.

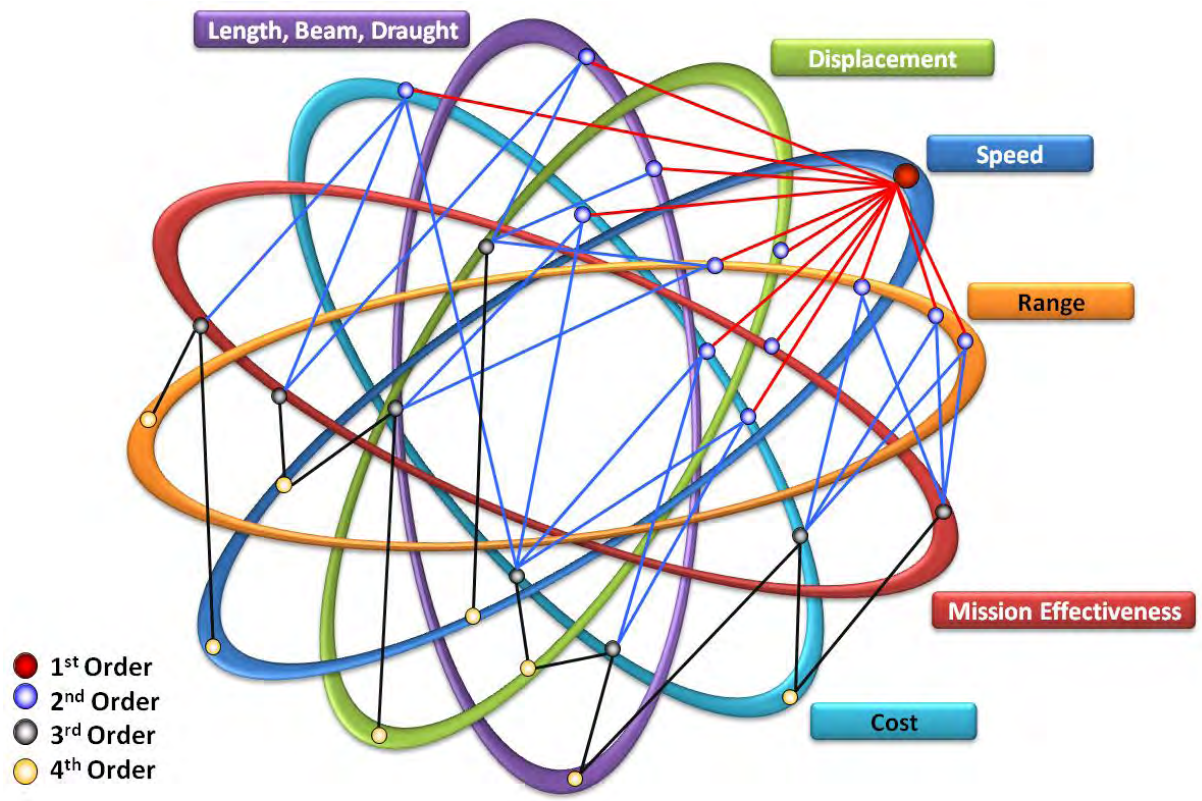

Figure 5 – Ship Design Interdependencies and Effects

Moreover, when the aspects of the design process are taken in isolation in a sequential manner as shown in Figure 4, the process is handicapped by its inability to quickly react to external constraints influencing trade offs. Table 7 shows non-exhaustive lists of constraints in the industrial, organisational, and political domains which may affect the design process.[39]

[39] UK Ministry of Defence (MOD), *Warship Engineering Management Guide, MAP 01-020*, 4.

Table 7 - Constraints on Ship Design Process

Industrial and Market	Organisational and Relational	Strategic and Political
• Minimise building time. • Consider foreign sales potential. • Reduce manpower on the ship. • Reduce specialized manpower on the ship. • Minimise the maintenance load required at the ship. • Simplify production process in the shipyard. • Fit up-to-date equipment which is being concurrently developed with the ship. • Minimise time in refit. • Minimise time in port. • Comply with international rules existing or likely to come into force. • Minimise training load to operate ship	• Structure of the design organisation. • Relationship of designer with customer. • Attitude of design organisation to the latest design techniques. • Past design type ship data available. • Countries of origin of designer or design methods. • The need or ability to buy-in talent to the design team. • Specialisation and training of the design team. • State of the art in various fields. • Computer facilities directly on tap and their limitations. • Quality of general engineering data directly available. • Research facilities directly under designers' control. • The idiosyncrasies, prejudices, rivalries, personalities of the design team	• Physical and natural environment. • Political climate. • The exact manner in which money is funded. • The need to comply with new laws (e.g. health and safety during build). • The political necessity to support ailing shipyards. • The strategic and political necessity to spread work around shipyards. • The decision to reduce direct government research. • Collaboration with NATO allies on equipment

Source: UK Ministry of Defence. *Warship Engineering Management Guide*. 2007.

Viewing the problem using the systems engineering V-model approach highlights more saliently the necessary need to plan for verification and validation (V&V). The V-diagram in Figure 6 represents how, with time, the engineering process evolves from design specifications to construction, and then through systems integration, trials and testing until capabilities can be demonstrated for acceptance.[40] Verification, the confirmation by examination and provision of objective evidence that the characteristics and behaviour of itemized equipment and systems comply with the requirements specified in the SRD, is generally performed while a system is

[40] Ibid., 5

being integrated. Validation, the confirmation by examination and provision of objective evidence that capabilities enabled by the integration of equipment and systems satisfy the intended use and needs defined in the SOR, is generally performed upon completion of product acceptance.[41]

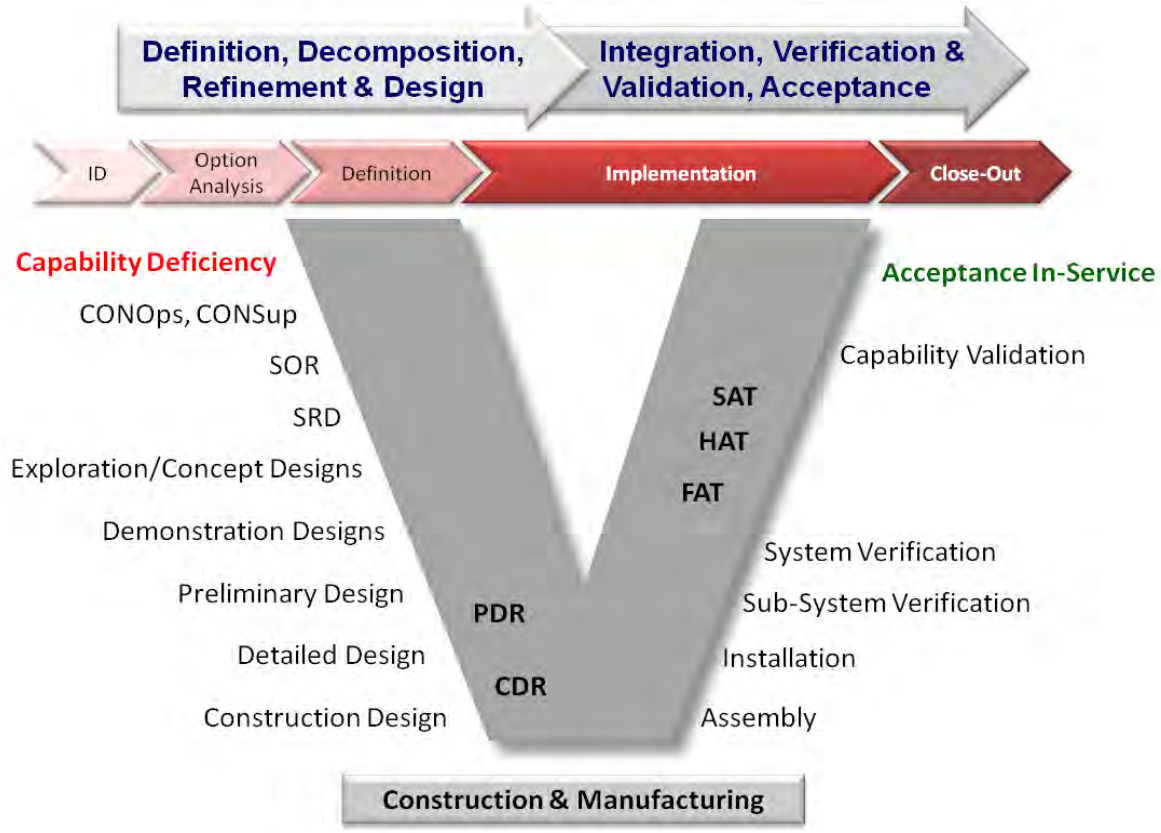

Figure 6 - Systems Engineering V-Model for Ship Design Process

Source: Adapted from Department of Defense - Systems Management College. *Systems Engineering Fundamentals*. 2001.

[41] Ibid., 13

Verification criteria confirm that "the systems were built right" by addressing measures of performance (MOPs) whereas validation criteria confirm that "the right systems were built" by addressing measures of effectiveness (MOEs).[42] MOEs describe mission effectiveness in specific scenarios such as conflict duration, territory lost or gained, casualties, and targets destroyed. MOPs such as maximum sustained speed, endurance and signatures define the performance of the ship systems independently of mission scenarios. Design parameters providing the physical description of the ship systems determine the MOPs, and MOPs determine MOEs.[43] In this study, design parameters and MOPs will be explicitly defined as ship's capability levels, and MOEs will be associated with CF operations and naval functions level of success.

The challenge is that with an inefficient procurement process lasting 10 to 15 years and a time-consuming, sequential and ineffective ship design process, inexperienced project staffs have no reliable and credible analytical tool with sufficient fidelity to ascertain, within an acceptable level of risk, how their cost-capability trade-offs will likely achieve the verified systems performance and provide the validated capability, within budget, until the project is completed.

To capture and analyse the significant interdependencies between the design parameters, which ultimately determine cost and risk, domain knowledge and experience must be applied onto a systems engineering decision tool promoting concurrent task completion and instantaneous forecasting visualisation.[44] Such an approach would optimize the design process and alleviate some shortcomings in the procurement processes to ensure effective and efficient product development.

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[42] Ibid., 99

[43] Brown and Thomas, *Reengineering the Naval Ship Concept Design Process*, 2.

[44] UK Ministry of Defence (MOD), *Warship Engineering Management Guide, MAP 01-020*, 67.

CHAPTER 2 - STRATEGIC PLANNING AND PRIORITIZATION

UNIFIED TRADE-OFF ENVIRONMENT

The Aerospace Systems Design Laboratory (ASDL) of the Georgia Institute of Technology has been performing Design Space Analysis (DSA) studies using their Unified Trade-off Environment (UTE) process since the early 1990s. The UTE process is a methodical design approach which was developed by ASDL for the aero-propulsion industry and was subsequently adapted in the late 1990s to warship applications for the US Naval Surface Warfare Center through sponsorship by the Office of Naval Research (ONR) in collaboration with the Center for Innovation in Ship Design (CISD).[45]

The UTE process uses systems engineering principles to establish the complex interdependencies between hierarchical factors such as operational requirements, design parameters and technology selection. Furthermore, this process establishes traceable relationships to determine the impacts of the design characteristics on performance and costs, and their sensitivities to initial assumptions.[46] The design space can thus be optimally analysed by performing multidimensional space analysis in real-time as opposed to sequential point design explorations as generalized in Figure 7.

[45] Jeffrey Koleser and others, "A Decision Making Framework for Naval Ship Design and Acquisition," (2008).

[46] Ibid.

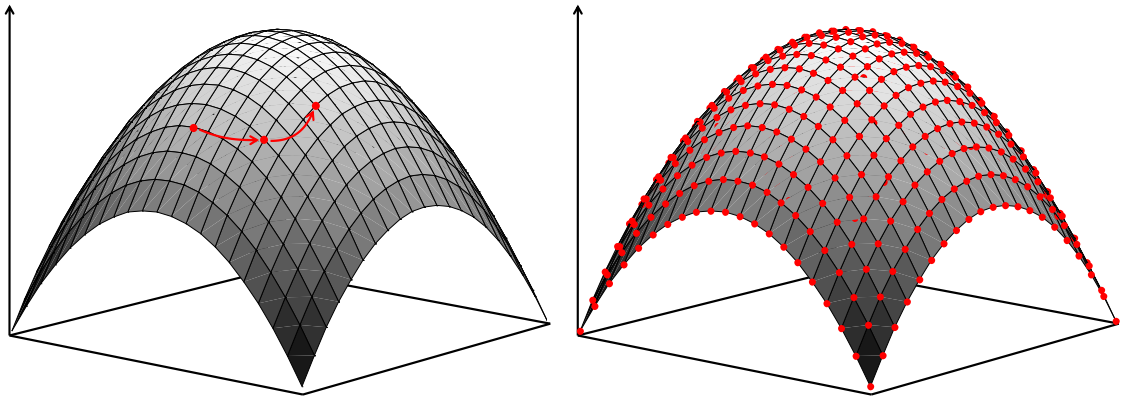

Figure 7 - Point Design Explorations compared to the UTE Design Space Analysis

Source: Aerospace Systems Design Laboratory of Georgia Institute of Technology

Implementation of the UTE process is divided into five iterative phases, as illustrated in Figure 8, culminating into a metamodel environment enabling the examination and visualization of critical design interdependencies. This paper specifically examines the first phase of the UTE process, namely problem definition. This phase is most vital because it provides decision-makers with a structured, traceable, and transparent framework to create relationships between several levels of abstraction from geopolitical-level military ambitions to tactical-level ships capabilities. Abstraction during the conceptual phase of the design process allows the hierarchical functional decomposition of complex design problems into selective manageable size aspects that can be examined more efficiently.[47] The usefulness of the subsequent phases is predicated on how well the right information was captured and linked during the problem definition phase using the ASDL Strategic Planning and Prioritization (SP2) process.

[47] Wim Zeiler, Perica Savanovic and Emile M. C. J. Quanjel, "Design Decision Support for the Conceptual Phase of the Design Process" (Hong Kong, School of Design, The Hong Kong Polytechnic University, 12 - 15 November 2007, 2007), http://www.sd.polyu.edu.hk/iasdr/proceeding/papers/Design%20Decision%20support%20for%20the%20conceptual%20phase.pdf (accessed 21 April 2011).

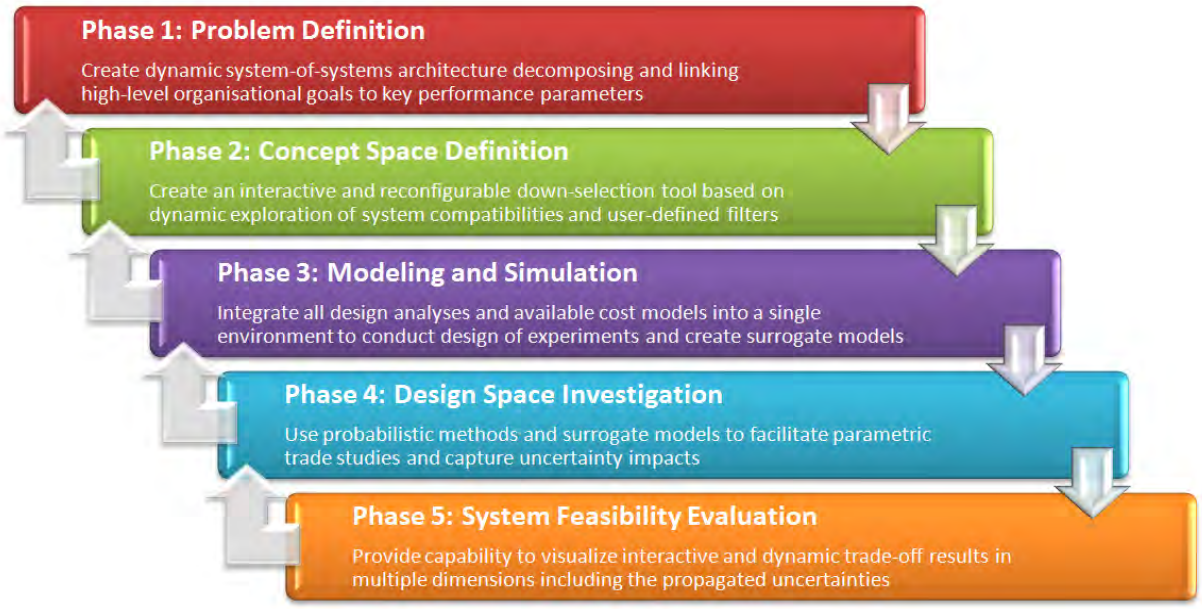

Figure 8 - Unified Trade-off Environment (UTE) Process

Source: Aerospace Systems Design Laboratory of Georgia Institute of Technology

STRATEGIC PLANNING AN DPRIORITIZATION

The Strategic Planning and Prioritization (SP2) process is an evolution of quality engineering methods, including quality function deployment (QFD) that incorporates various dynamic aspects to address the shortcomings in traditional resource allocation approaches.[48] Through a series of facilitated workshops with subject matter experts (SMEs) and modern voting techniques, models are created enabling the mapping of options to any desired level of detail as information becomes available. The results from the SP2 process are then synthesized into a dynamic and portable decision-making support tool allowing managers to visualize and assess multiple scenarios through "what if" games, whilst reducing individual biases. The SP2 process can also serve as the foundation for strategic road mapping and quantitative technology assessment and tracking.[49] Figure 9 illustrates the SP2 process and its associated steps as applied in this study. The tailored process used in this research starts with the scope of planning from the organizational goals established by the CFDS down to the ship's capabilities enabling the maritime contribution to the CF domestic and expeditionary military operations.

The translation of national policy goals into military action must be conducted in a way that ensures clarity, unity of purpose, and economy of effort. Accordingly, military activities have traditionally been categorized into three hierarchical but overlapping levels: strategic, operational, and tactical.[50] As advocated by Hughes (2008), it is recognized that upward unity of purpose is difficult because politics and warfare must arrive at a goal-driven, united logic while communicating with different grammars. Lateral unity of action is also difficult because

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[48] Michelle R. Kirby, Chis Raczynski and Dimitri Mavris, "An Approach for Strategic Planning of Future Technology Portfolios" (Wichita, Kansas, American Institute of Aeronautics and Astronautics, 25-27 September 2006, 2006).

[49] Ibid.

[50] Canada. Department of National Defence, *B-GJ-005-314/FP-000 CF Joint Force Protection Doctrine* (Ottawa, ON: Joint Doctrine Branch, November 2006), 1-7.

different services see the same problem through different lenses and aspire to different solutions.[51] In this study, the UTE SP2 process will be used to decompose, prioritize and recompose requirements through these levels enabling both the descending "top-down" approach from geopolitical aspirations and the ascending "bottom-up" approach from system-level capabilities. As it will be seen, the SP2 process generates upward, lateral and downward connections to generate a collectively created shared picture.

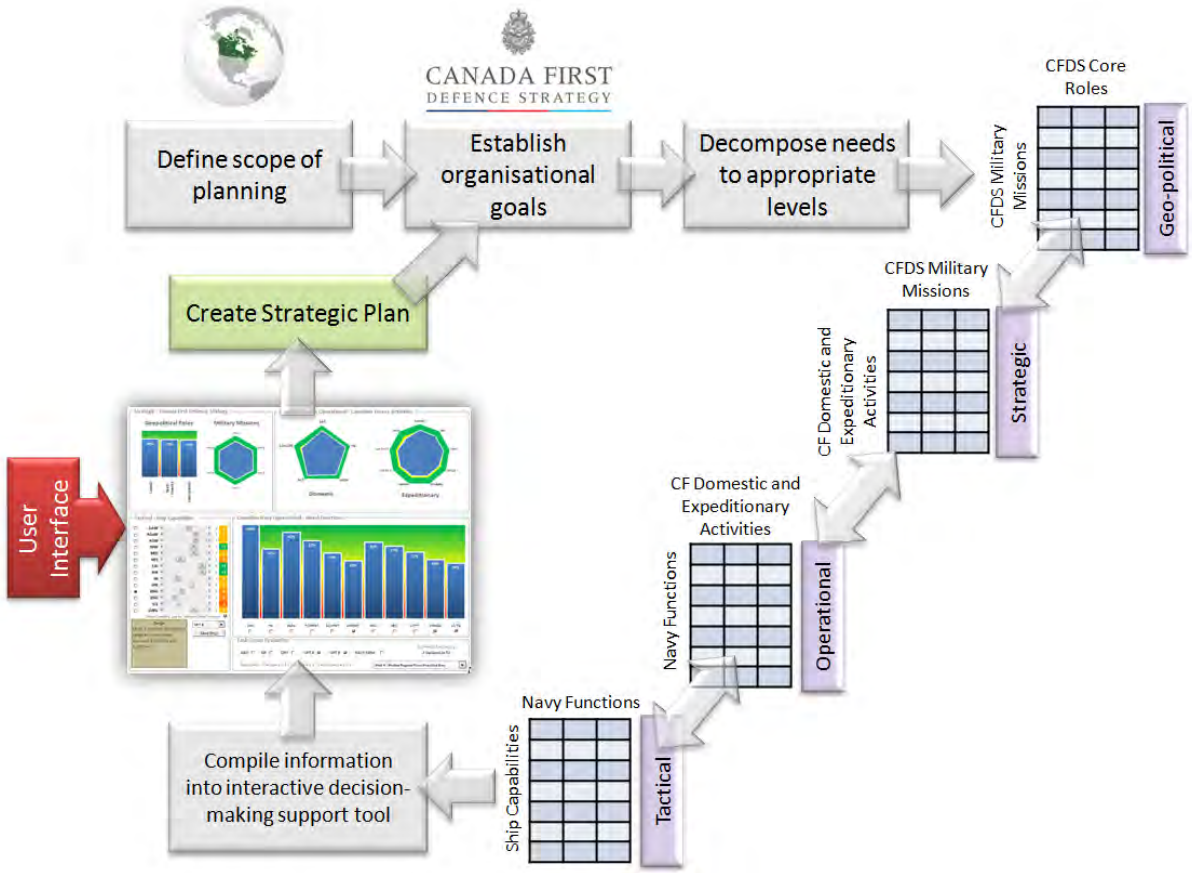

Figure 9 - Strategic Planning and Prioritization (SP2) Process

Source: Aerospace Systems Design Laboratory of Georgia Institute of Technology

[51] Wayne P. Hughes Jr., "Implementing the Seapower Strategy," *Naval War College Review* 61, no. 2 (Spring 2008), 47, http://www.usnwc.edu/Publications/Naval-War-College-Review/2008---Spring.aspx (accessed 8 April 2011).

For decision-making, there is a need to prioritize certain factors by highlighting the relative higher impact of the more important areas of the whole system-of-systems.[52] The relative strength of attributes will therefore be established amongst geopolitical-level military ambitions (e.g., defend North America), strategic-level military missions, operational-level military activities and naval functions, and ship-level capabilities (e.g., anti air warfare, maximum sustained speed). The process could be tailored to continue down to the systems-level functional attributes (e.g., ability to autonomously detect and engage targets) all the way down to an applicable system (e.g., Close-In Weapon System) or a possible technical solution (e.g., Goalkeeper, Meroka, Millenium GDM-008, RIM-116 RAM, SeaRAM) complete with technical specifications and cost data. However, as explained in Chapter 1, imposing an equipment-specific solution within a procurement process lasting 10 to 15 years only predispose an obsolete system at initial operational capability (IOC) delivery. For this reason, this study will not go further than the ship's capability level, namely the capability-based system level.

The voting and prioritization between hierarchical levels is performed using customizable scales that qualitatively define the relationships and then translate them quantitatively using non-linear utility function in order to discriminate the strength of the relationships. Criteria and categories suggested by the DND / CF integrated risk management guidelines were used to create scales assigning numerical values to a qualitative (subjective) assessment in order to determine the impact and frequency of a task or function.[53] The numerical values may change depending on the nature of the question asked or the requirement to perform sensitivity analysis. Table 8 shows the impact assessment criteria for how critical is a given task in achieving or

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[52] Johansson and others, *Knowledge Maturity as a Means to Support Decision Making during Product-Service Systems Development Projects in the Aerospace Sector*, 41.

[53] Canada. Department of National Defence, *DND / CF Integrated Risk Management Guidelines* (Ottawa, ON: Directorate General Safety Programme, 2007), 6.

supporting a given higher-level objective. Table 9 shows the frequency assessment criteria for how likely is a given task to be used or required to achieve or support a higher-level objective. Table 10 shows the overall effect of a given task on the achievement or support of a higher-level objective when computing both the impact and frequency voting.

Table 8 – Impact Critically Assessment Scale

Evaluation	Value	Impact	Consequence
Very High (VH)	1.00	Critical	Failure to achieve higher-level requirements.
High (H)	0.85	Major	Threaten higher-level requirements. Some higher-level requirements at risk, overall marginal effectiveness.
Moderate (M)	0.65	Moderate	Necessitates significant adjustment to higher-level requirements. Higher-level requirements achieved with day-to-day crisis issues. Supporting tasks at risk.
Low (L)	0.40	Minor	Threaten an element of the higher-level requirements. Most higher-level requirements met.
Very Low (VL)	0.15	Insignificant	Lower consequences / impact. Higher-level requirements achieved with minor shortfalls.
Not Applicable (NA)	0.00	None	None.

Source: Adapted from Department of National Defence. *DND / CF Integrated Risk Management Guidelines*. 2007.

Table 9 – Frequency Assessment Scale

Evaluation	Value	Frequency	Requirement
Very High (VH)	1.00	Always	Expected to occur in most circumstances.
High (H)	0.85	Likely	Will probably occur in most circumstances.
Moderate (M)	0.65	Possibly	Could occur at some time.
Low (L)	0.40	Unlikely	Not expected to occur.
Very Low (VL)	0.15	Rarely	Occurs in exceptional circumstances only.
Not Applicable (NA)	0.00	Never	None.

Source: Adapted from Department of National Defence. *DND / CF Integrated Risk Management Guidelines*. 2007.

Table 10 – Overall Effect Evaluation

Effect		Impact					
		Critical	**Major**	**Moderate**	**Minor**	**Insignificant**	**None**
Frequency	**Always**	VH	VH	H	M	L	NA
	Likely	VH	H	M	L	L	NA
	Possibly	H	H	M	L	VL	NA
	Unlikely	H	M	L	VL	VL	NA
	Rarely	M	L	VL	VL	VL	NA
	Never	NA	NA	NA	NA	NA	NA

Source: Adapted from Department of National Defence. *DND / CF Integrated Risk Management Guidelines*. 2007.

GEOPOLITICAL ROLES AND STRATEGIC MILITARY MISSIONS

The CFDS geopolitical-level military ambitions, in the form of three core roles, were mapped to the CFDS strategic-level military missions in terms of impact and frequency resulting in an overall effect. The impact question was how critical is a given strategic-level military mission in achieving or supporting a given geopolitical-level military role? The voting results in Figure 10 show that responding to a terrorist attack was the military mission most contributing to

all core roles, followed very closely by conducting daily domestic and continental operations. Defending North America was the role most demanding from all the military missions.

The frequency question was how likely is a given strategic-level military mission to be used or required to achieve or support a given geopolitical-level military role? The voting results in Figure 11 show that conducting daily domestic and continental operations was clearly the military mission most likely required to contributing to all core roles, followed by supporting a major international event in Canada. Defending North America was the role most frequently supported by all the military missions.

The overall effect of a given strategic-level military mission on the achievement or support of a given political-level military role, when considering both the impact and frequency, is illustrated in Figure 12. The SP2 voting results show that the most effective military mission alternated from domestic to expeditionary missions starting with conducting daily domestic and continental operations followed by deploying forces in response to crisis elsewhere in the world for shorter periods, and so on. This alternating trend may suggest that both domestic and expeditionary missions are evenly important. However, when compared using the normalization to the minimum results, conducting daily domestic and continental operations is clearly the most important mission as it is 5.7 times more important than responding to a major terrorist attack, the mission with the least impact on the military roles. Defending Canada was the role most contributed to by all military missions followed by defending North America. This mapping facilitates the evaluation of the measures of effectiveness (MOEs) for the CFDS geopolitical-level military core roles.

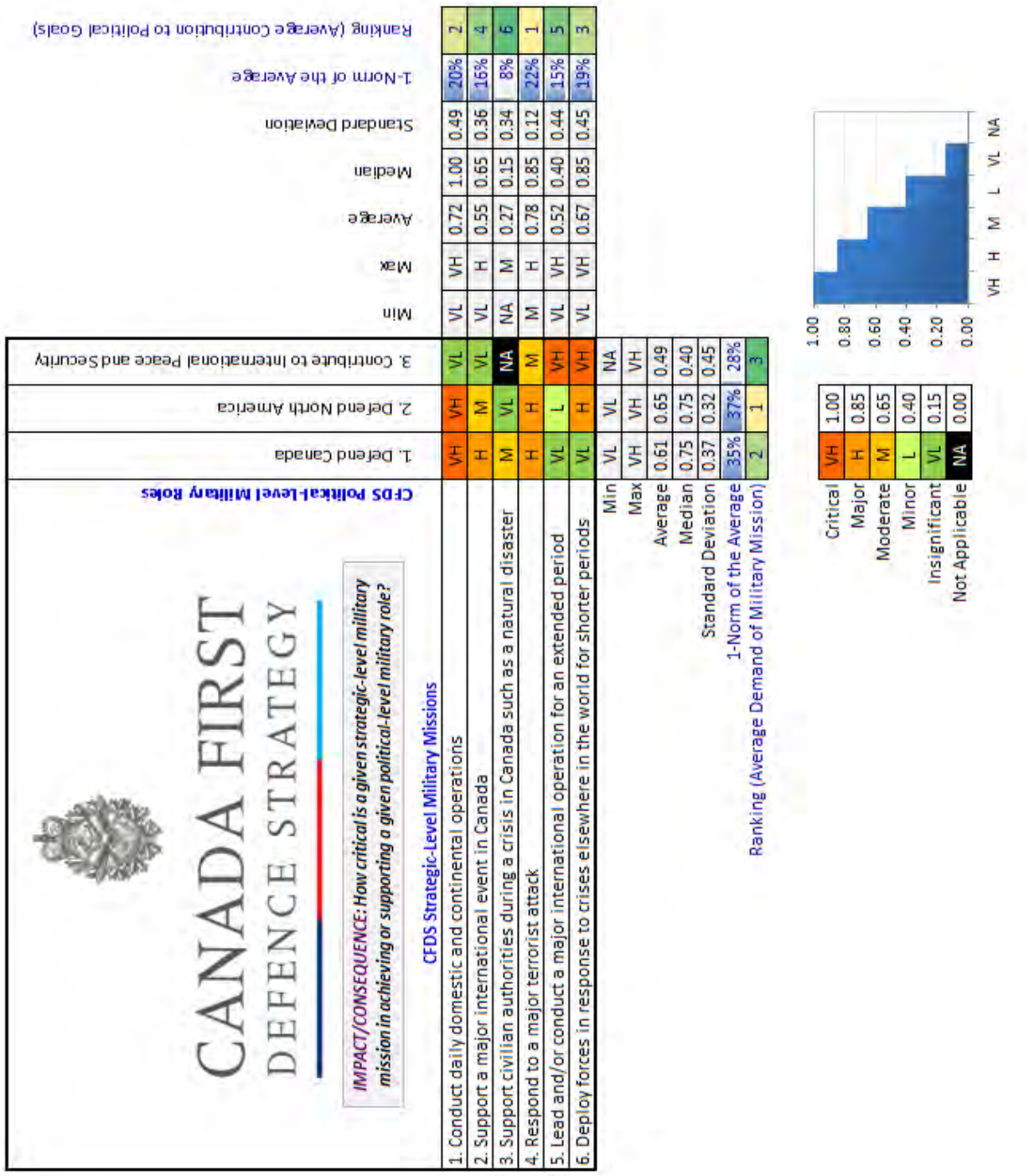

Figure 10 – Impact Assessment of CFDS Missions and Roles

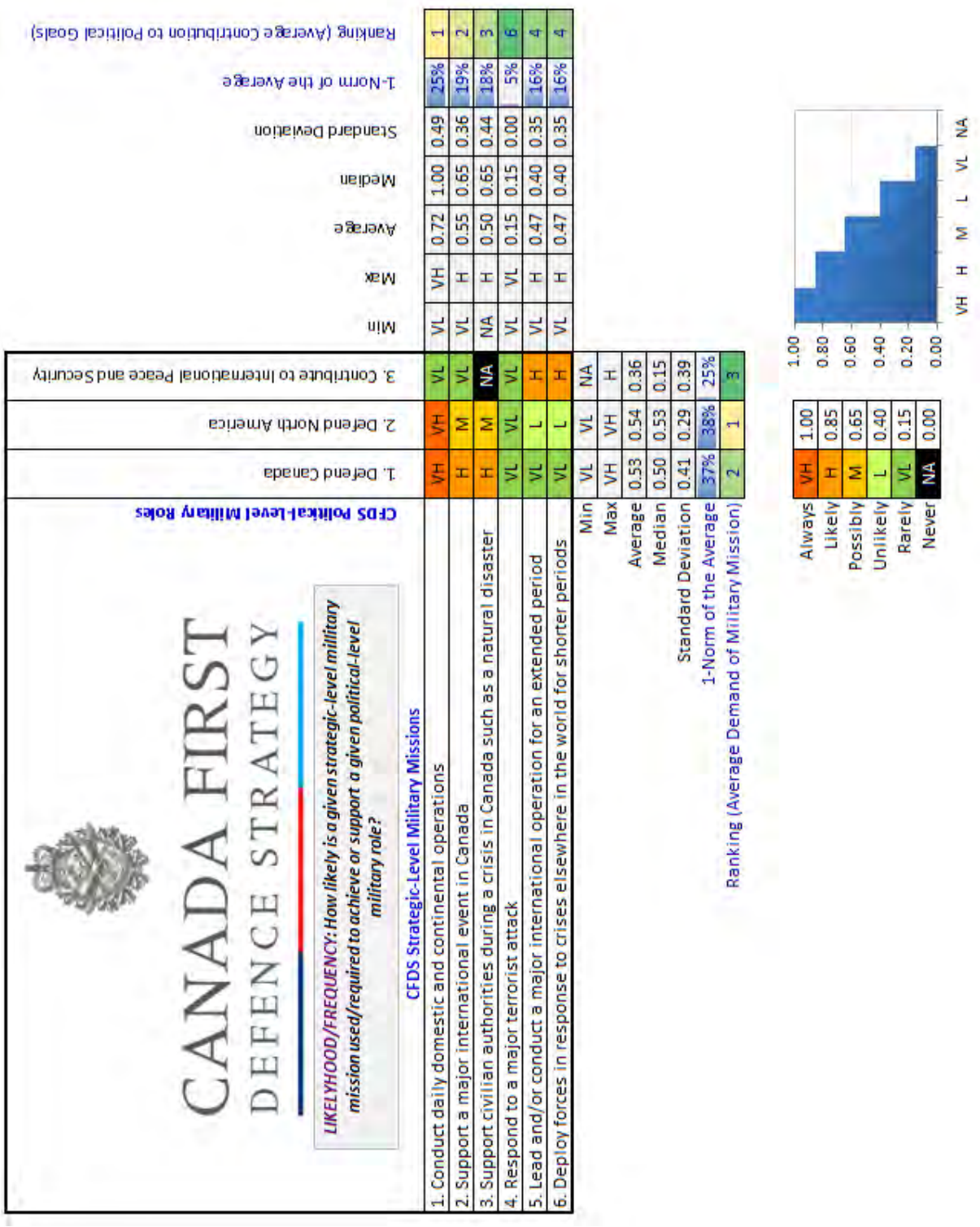

Figure 11 – Frequency Assessment of CFDS Missions and Roles

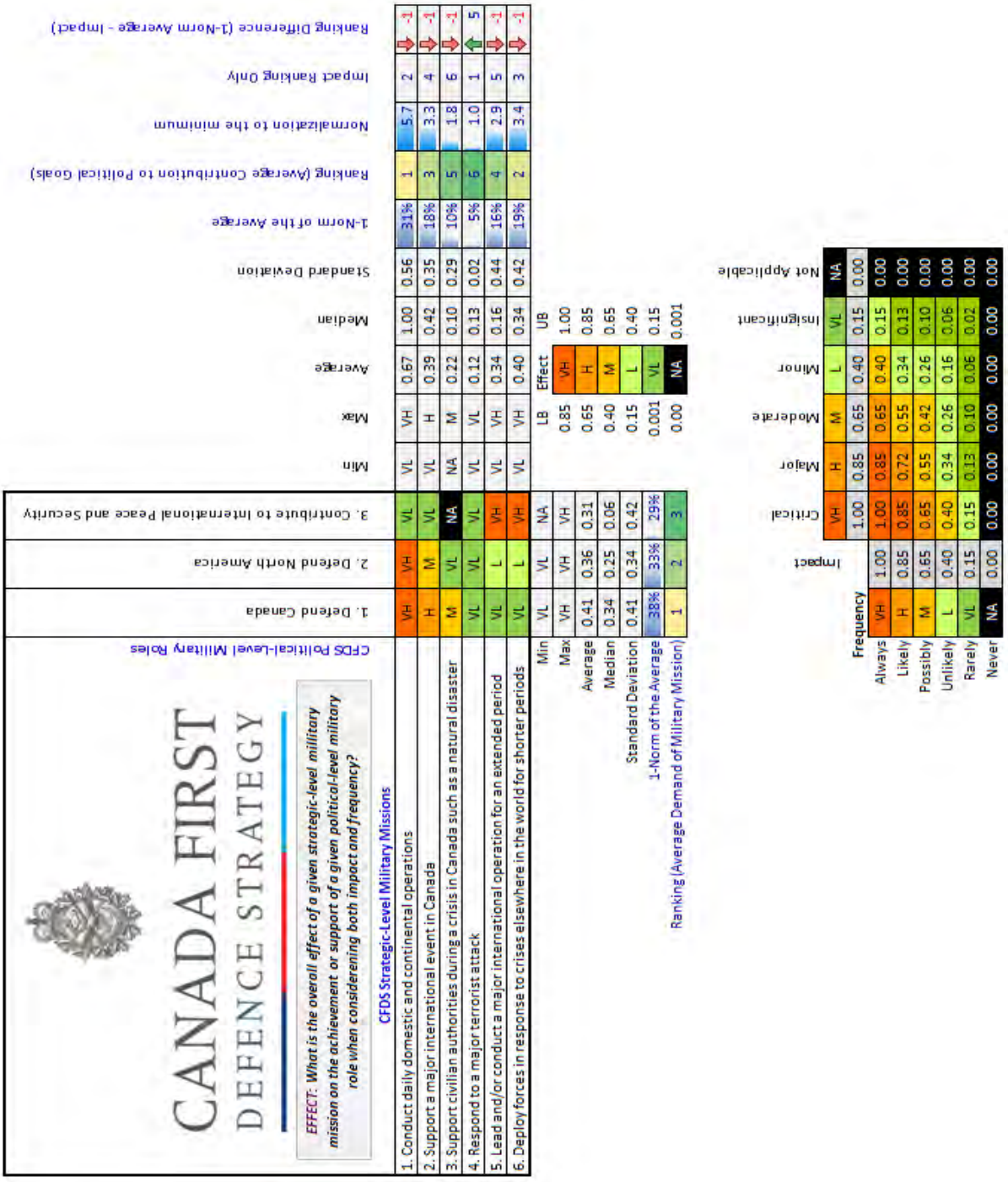

Figure 12 – Overall Effect Analysis of CFDS Missions and Roles

STRATEGIC MISSIONS AND JOINT OPERATIONAL ACTIVITIES

After the last Halifax-class frigate was commissioned in 1996, among the first attempts at dealing with the post Cold War era and the repercussions of "Revolution in Military Affairs" (RMA) was *Defence Strategy 2020*. Released in June 1999, this document identified both the challenges and opportunities facing the Department of National Defence (DND) and the CF as they tried to adapt to the changes in a rapidly evolving, complex and unpredictable world.[54] Force planning scenarios (FPS) were promulgated describing the anticipated activities that the CF would participate in order to meet future security and defence challenges within the spectrum of conflicts (see Table 11).[55] The FPS included joint tasks for the army, navy and air force working in conjunction with a number of OGDs and NGOs, and constituted a good point of departure for force development.[56]

Table 11 - Force Planning Scenarios 2001

Scenario	Description
Search and Rescue	Sub-scenarios include rescue from a ship at sea, search and rescue of an overdue hunting party in the North, and the rescue of survivors from a major airliner downed in a remote area in the North.
Disaster Relief in Canada	Assist in the relief of human suffering and assist authorities to re-establish the local infrastructure after a major earthquake on the west coast of Canada.
International Humanitarian Assistance	As part of a UN operation, assist with the delivery of relief supplies to refugees amassed in a central African nation.
Surveillance \ Control of Canadian Territory and Approaches	Assist Other Government Departments and law enforcement agencies in identifying, tracking and, if required, intercepting platforms suspected of carrying contraband goods or illegal immigrants before or after entering Canadian territory.
Protection and Evacuation of Canadians Overseas	Assist DFAIT, as part of a combined force, in the protection and evacuation of Canadian nationals in a foreign nation threatened by imminent conflict.

[54] Canada. Department of National Defence, *Shaping the Future of the Canadian Forces: A Strategy for 2020*, 18.

[55] Canada. Department of National Defence, *Concept Paper - Departmental Force Planning Scenarios (FPS)* (Ottawa, ON: VCDS - Director General Strategic Planning, 2003).

[56] A. Bourque and C. Eisler, *Fleet Mix Study: Establishing the Historical and Policy Basis for the Maritime Vignettes (TM 2008-38)* (Ottawa, ON: Defence Research and Development Canada (DRDC), Centre for Operational Research and Analysis (CORA), November 2008), 3.

Scenario	Description
Peace Support Operations (Chapter 6)	Participate as part of a UN peacekeeping force maintaining a cease-fire and assisting in the creation of a stable and secure environment where peace building can take place.
Aid of the Civil Power	Assist civil authorities in the establishment of law and order in an area where lawlessness has occurred as the result of disputes over the control of water rights in a time of severe drought.
National Sovereignty / Interests Enforcement	Claiming extended jurisdiction under UNCLOS III, Canada has requested the cessation of seabed exploitation operations by a foreign nation. The CF will assist OGDs in the enforcement of Canadian claims.
Peace Support Operations (Chapter 7)	At the request of a foreign nation, as part of a UN coalition, the CF will participate in operations to restore pre-conflict boundaries and return control of an occupied area to the control of the rightful country.
Defence of Canada / US Territory	In cooperation with US forces, the CF will defend Canada/US territory against potential threats initiated by an emerging world power as a result of Canadian and American support for a foreign military operation.
Collective Defence	As part of a NATO force, the CF will attempt to deter and, if necessary, contain an attack on NATO territory and conduct restoration operations.

Source: Department of National Defence. *Leadmark: The Navy's Strategy for 2020*. 2001.

Although replaced by several generations of classified force development scenarios (FDS) since 2005,[57] the 2001 FPS were used as inspiration along with other military doctrinal documents, namely the CF joint publication on operations[58] and the Canada Command direction to domestic operations,[59] to create a list of operational-level domestic and expeditionary military activities. Domestic operations are conducted by the CF joint components within the confines of the 200 nautical mile exclusive economic zones (EEZ), the 12 nautical mile territorial offshore waters, and inshore ports and approaches. Domestic operations include assistance during civil

[57] Michael L. Roi, Peter Archambault and Charles Morrisey, *The First Cycle of the Spiral Process to Develop New Force Development Scenarios (TM 2008-07)* (Ottawa, ON: Defence Research and Development Canada (DRDC), Centre for Operational Research and Analysis (CORA), Chief Force Development, February 2008), 1.

[58] Canada. Department of National Defence, *B-GJ-005-300/FP-001 Canadian Forces Joint Publication - Operations (CFJP 3.0)* (Ottawa, ON: Joint Doctrine Branch, Canadian Forces Experimentation Centre, July 2010).

[59] Canada. Department of National Defence, *Canada Command Direction for Domestic Operations* (Ottawa, ON: Canada Command Headquarters, 1 February 2006).

emergencies, support to national development goals, support to the maintenance of public order and security, and conduct of surveillance and control operations (see Table 12).[60] Expeditionary operations are usually conducted by combined forces (multinational) with civilian-military cooperation (CIMIC). Expeditionary operations include North American continental defence with the US and international operations with major allies such as the UN and NATO forces (see Table 13).[61]

Table 12 - CF Domestic Operations and Activities

Operation	Activities
Air and Maritime Search and Rescue (SAR)	SAR is the use of aircraft, surface craft, submarines, specialized rescue teams, and equipment to search for and rescue personnel in distress on land or at sea. In Canada, SAR is inherently an integrated joint activity because it involves coordination between the CF, the Coast Guard (Department of Transport), and the RCMP.
Humanitarian Assistance	This includes any action undertaken within the Canadian territory to save lives, to prevent or alleviate human suffering, or to mitigate property damage. There are three categories of domestic humanitarian-assistance operations. Emergency civil assistance undertaken in response to natural or human-induced disasters. Search for missing persons on land, not resulting from an aeronautical or maritime incident, sometimes referred to as ground search and rescue (GSAR). Other humanitarian assistance responses to requests arising from events or situations that are less than the scale of a provincially or locally declared emergency.
Assistance to Law Enforcement Agencies (ALEA)	Although the CF does not have a standing mandate to enforce the laws of Canada, there may be instances including disturbance of the peace, when law enforcement agencies may seek CF assistance in discharging their duties. Such support may include: assistance to the RCMP for counter-terrorism; assistance to provincial police forces; assistance to Correctional Service Canada for perimeter security at federal penitentiaries; support to federal counter drug activities; assistance to the Department of Natural Resources for hazardous materials advice and service; Chemical, Biological, Radiological and Nuclear (CBRN) assistance the Health Canada; and assistance to the Department of Fisheries and Oceans (DFO) for fisheries protection.
Aid to Civil Power	In recognition that a riot or disturbance may exceed the capability of provincial/territorial civil authorities, Part VI of the NDA provides a process by which a province and territory may request CF support, through the CDS, for the purpose of suppressing or preventing a riot or disturbance.

[60] Canada. Department of National Defence, *B-GJ-005-300/FP-001 Canadian Forces Joint Publication - Operations (CFJP 3.0)*, 6-1.

[61] Ibid., 7-1

Operation	Activities
Sovereignty Operations	This includes exercising Canada's sovereignty which is the result of surveillance, presence, and control. It is knowing who is in, and who is approaching, sovereign territory and what their intentions may be. The CF plays an important role in aiding the Government of Canada demonstrate its sovereignty by providing a military presence throughout the country, including in the Arctic, and promoting CF capability and resolve to domestic and international audiences. This presence enables the government to remain aware of activities taking place within Canadian territory and air/maritime approaches.

Source: Adapted from Department of National Defence. *Canada Command Direction for Domestic Oprations.* 2006.

Table 13 - CF Expeditionary Operations and Activities

Operation	Activities
International Humanitarian Relief Operations (HUMRO)	The GoC may direct the conduct of a HUMRO to relieve or reduce the impact of natural or man-made disasters in countries or regions outside of Canada. The nature of the CF's contribution to a HUMRO will depend on a variety of factors such as: the resources already being supplied by other nations and/or agencies, the CF's capacity to contribute to the particular requirements of the HUMRO, and the accommodation for other operational priorities.
Non-combatant Evacuation Operations (NEO)	A NEO is the evacuation of Canadian citizens located in a foreign country, who are in danger or otherwise threatened by hostile actions, natural disasters, or other calamities. In such situations the Department of Foreign Affairs and International Trade (DFAIT) may request the assistance of the CF to conduct a NEO. The CF will respond positively to such a request by providing logistics, security, and other support as required up to and including a JTF.
Counter-Insurgency Operations (COINOPs)	The CF will normally conduct COINOPs as part of an alliance or coalition effort, in response to a request from the affected government or other legitimate authority such as the UN or NATO. While the specific capabilities required will depend on the scope and scale of the commitment made by the GoC, the CF must nonetheless be prepared to conduct the full range of combat and non-combat operations as circumstances dictate, including support to humanitarian assistance and civil-development tasks carried out as part of a comprehensive-approach strategy.
Canada-US (CANUS) Continental Operations	Since the Ogdensburg Agreement of 1940, Canadian and US maritime, land and air forces conduct numerous military training exercises together each year and are partners in both the NORAD agreement and the NATO. Combined activities include counter terrorism, counter drug, border protection, humanitarian assistance, disaster relief, and SAR.

Operation	Activities
Stabilization Activities	Stabilization activities comprise a range of combat and non-combat missions and tasks conducted in an area of conflict by military forces in conjunction with OGDs and NGOs to establish a climate of public safety and order within which the host-nation government can operate effectively and civil society can function. Stabilization activities include a wide range of missions and tasks, the most important being: security and control; support to security sector reform (SSR); support to civilian infrastructure and governance; and assistance to other government departments and agencies (OGDA).
NATO Response Force (NRF) Operations	To ensure that NATO plays an effective role in managing crises, and in countering threats or aggression against any ally, the alliance has created a standing NATO Response Force (NRF) as a rapid-response mechanism to exercise collective political will. Responsibilities include defending Allied countries and maintaining the sea lines of communications (SLOC) across the North Sea and English Channel and in the Mediterranean and Adriatic seas.
Peace Support Operations (PSO) (UN Chapter VI)	A PSO will normally be conducted under UN or NATO mandate. As such, a PSO may encompass combat or non-combat operations depending on the specific category of PSO being undertaken. The generally recognized categories of PSO under Chapter VI of the UN Charter are: conflict prevention, peacekeeping, peace building, and peacemaking.
Peace Enforcement (UN Chapter VII)	Peace enforcement involves operations undertaken under Chapter VII of the UN Charter which may include using combat capabilities to restore peace in areas of international or internal conflict. Activities are coercive and designed to deal with threats to international peace and security, breaches of the peace and acts of aggression - Article 39. Possible tasks for a peace enforcement mission can include: enforcing sanctions and embargoes; establishing and enforcing No-Fly-Zones; force protection of humanitarian operations; establishing and protecting "safe areas" or exclusion zones; and combat operations at a level of intensity required to restore a sustainable peace.
Major Combat Operations (MCO)	MCO is the term used to describe the most demanding of joint campaigns. In MCO campaigns, joint operations take place in a state usually characterized as a "state of war." MCO campaigns are characterized by frequent engagements that are widespread, intense, and often enduring. MCO is also mainly characterized by offensive and defensive tactical operations and activities.

Source: Department of National Defence. *B-GJ-005-GJ-300/FP-001 Canadian Forces Joint Publication – Operations (CFJP 3.0).* 2010

Both domestic and expeditionary operational-level military activities were mapped to the CFDS strategic-level military missions thus bridging the strategic and operational levels. Moreover, since the CFDS is a political document and military activities emanate from military doctrine, military and political domains are thus also bridged. The impact question was how critical is the ability to complete a given CF operational-level military activity in achieving or

supporting a given CFDS strategic-level military mission? The voting results in Figure 13 show that assisting law enforcement agencies was the military activity most contributing to all CFDS military missions, followed very closely by conducting sovereignty operations and conducting CANUS continental operations. The frequency question was how likely is a given CF operational-level military activity be used or required to achieve or support a given strategic-level military mission, in the event that mission occurs? The voting results in Figure 14 show that conducting sovereignty operations is the military activity most likely to be required followed by assisting law enforcement agencies.

The overall effect of a given CF operational-level military activity on the achievement or support of a given CFDS strategic-level military mission, when considering both the impact and frequency, is illustrated in Figure 15. The SP2 voting results show that conducting sovereignty operations was the most effective military activity followed by assisting law enforcement agencies. Conducting CANUS continental operations and stabilizations operations alternated for third position depending on whether or not the relative importance of the military missions was weighted by the effectiveness of the military missions on the military roles. This mapping facilitates the evaluation of the MOE for the CFDS military missions.

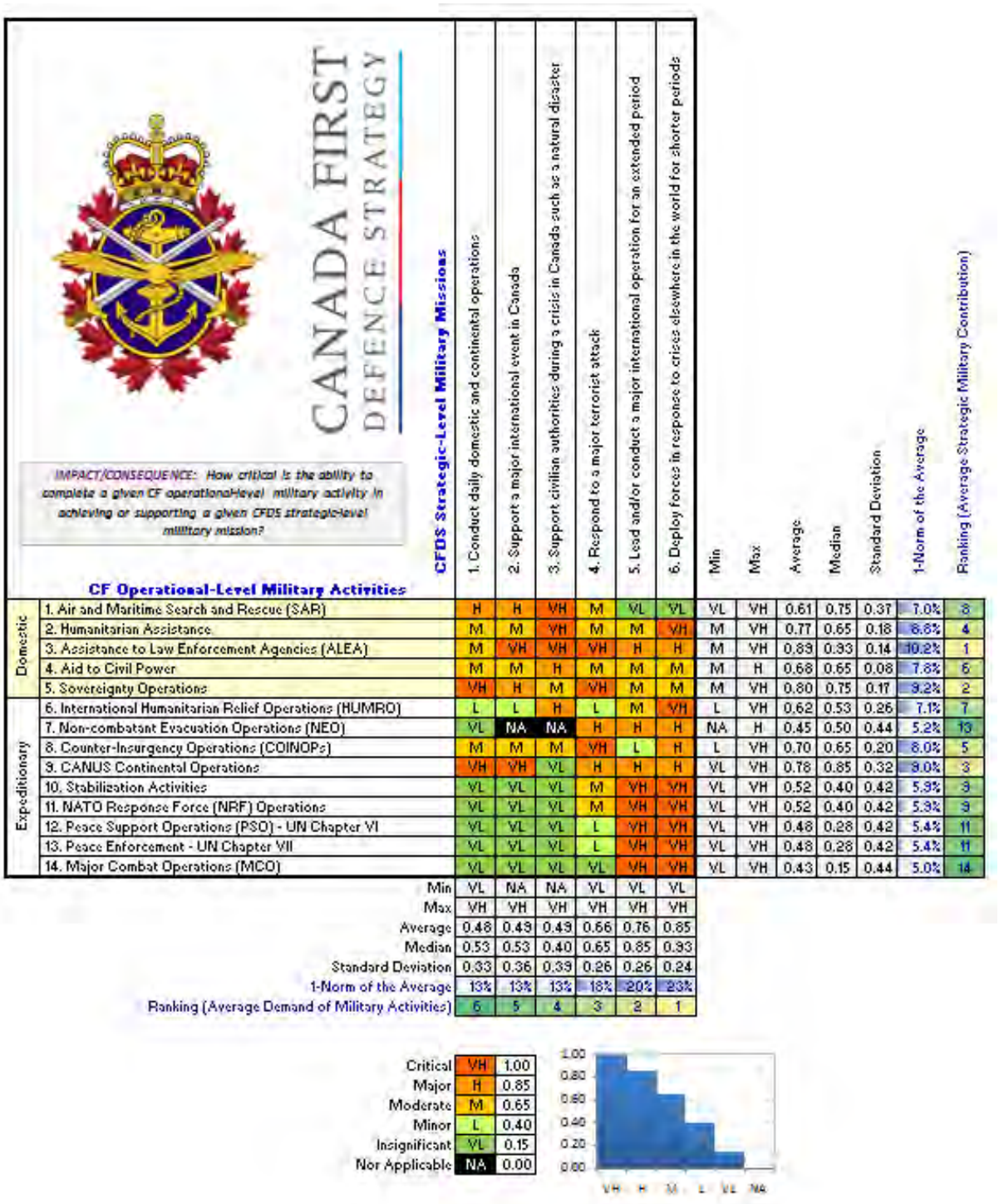

Figure 13 – Impact Assessment of CF Activities and CFDS Missions

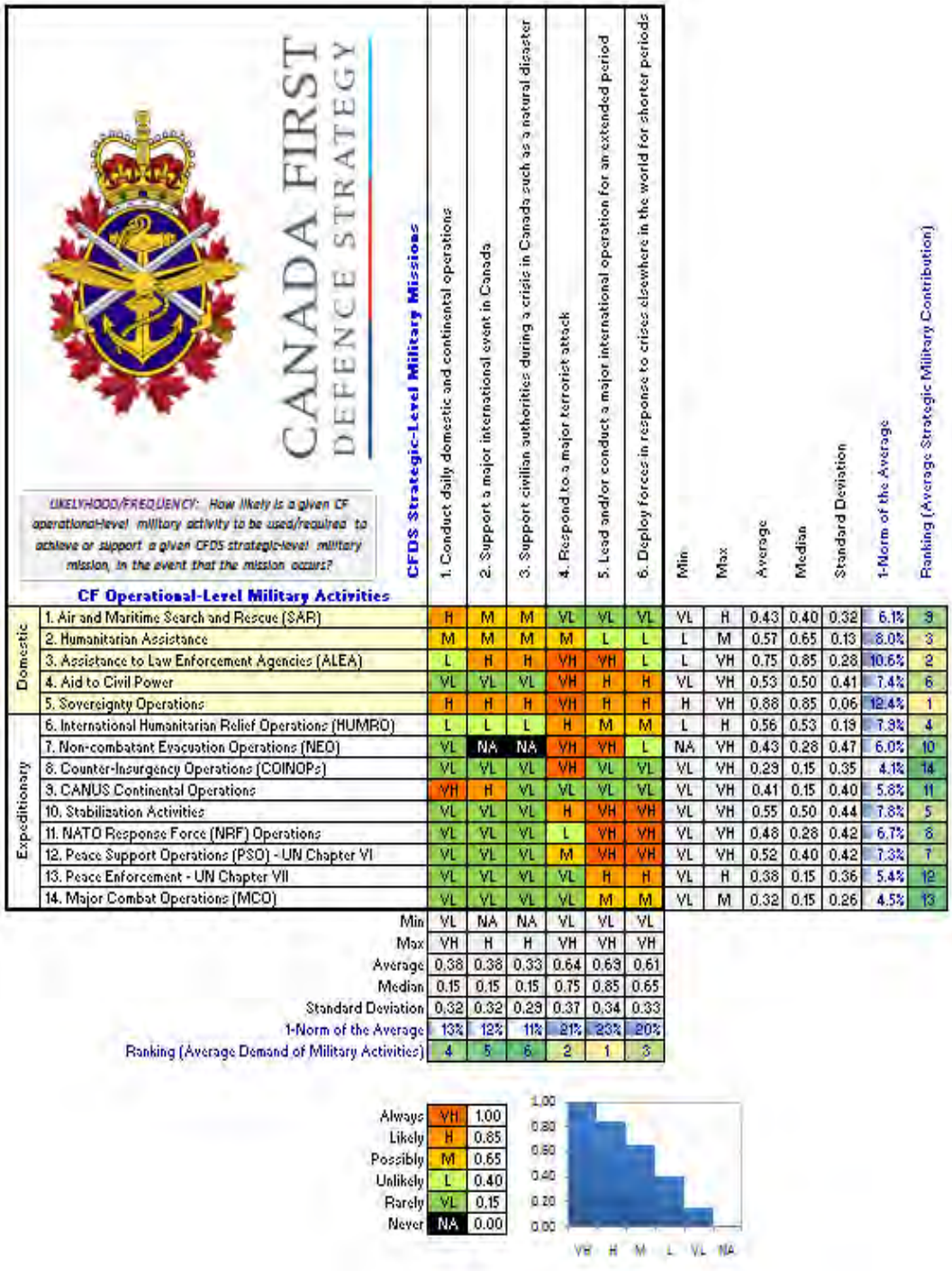

Figure 14 – Frequency Assessment of CF Activities and CFDS Missions

When studying how much of an effect a military activity has on the CFDS missions, there are three distinct groupings. The first grouping includes "sovereignty operations" and "assistance to law enforcement agencies." The second group is composed of "humanitarian assistance (domestic)," "CANUS continental operations," "stabilization activities," "NATO response force operations," and "peace support operations – UN chapter VI." And the third group contains the remainder of military activities. If one weighs the military missions by the effect they had on the military roles, and uses said weighting to in turn weigh the impact each military activity has on the military missions, the ranking of military activities changes. Under these weightings, "sovereignty operations" is the most critical military activity, while "assistance to law enforcement agencies" and "CANUS continental operations" comprise the second tier. The third group now includes "SAR," "HA," "STABOPS," "NRFOPS," and "PSO." The fourth tier includes "aid to civil power," "international HUMROPS," "NEO," "peace enforcement," and "major combat operations." "Counter-insurgency operations" is the sole military activity in the fifth tier.

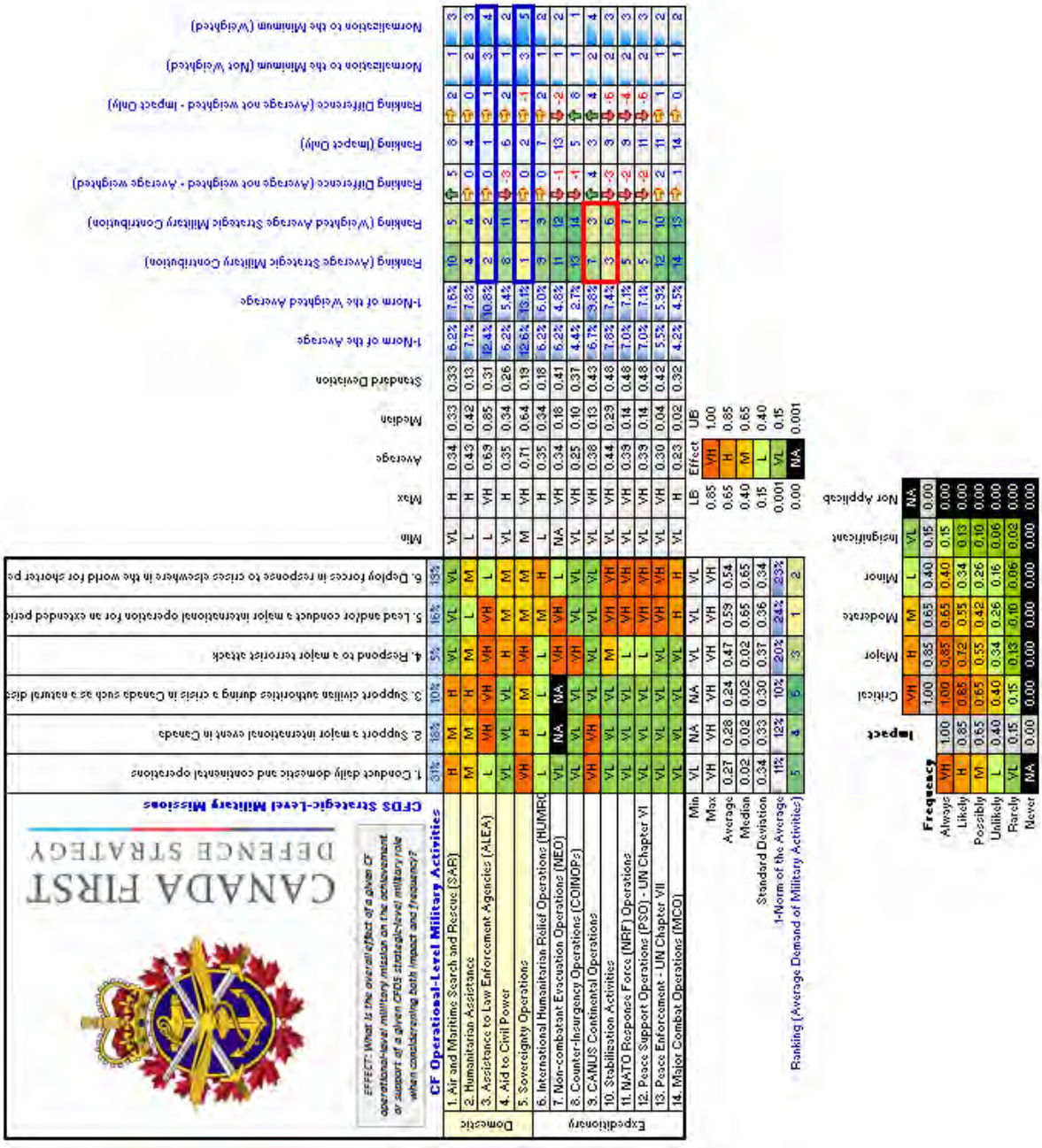

Figure 15 – Overall Effect Analysis of CF Activities and CFDS Missions

NAVAL CONTRIBUTION TO JOINT OPERATIONAL ACTIVITIES

To assess the contribution of the maritime component (MC) of the CF to domestic and expeditionary military operations, it is necessary to extract their naval aspects. To that end, the maritime progeny of *Defence Strategy 2020* is considered. Released in June 2001, *Leadmark 2020* articulated how the design of the next Canadian Navy would be influenced by the post Cold War experience but would also embrace the principles of capability-based planning, with a particular emphasis on an enhanced joint focus and allied interoperability. From this point forward the study is navy specific; this juncture is therefore where the land, air and special force CF components could diverge into their own environmental analysis.

Among the important proclamations of *Leadmark 2020* was ranking of the Canadian Navy in relation to other nations on the basis of inherent power and the political will to employ the fleet in a particular fashion. Like the Netherlands and Australia, Canada's navy was claimed to be a rank 3 - medium global force projection navy, surpassing regional (rank 4) and adjacent (rank 5) force projection navies (see Table 14). Medium global force projection navies may not possess the full range of capabilities of major global force projection navies such as France, England and the US, but they have credible niche capabilities which can be exploited at some distance in cooperation with other force projection navies.[62]

[62] Canada. Department of National Defence, *Leadmark: The Navy's Strategy for 2020* (Ottawa, ON: Directorate of Maritime Strategy, 2001), 44.

Table 14 - Naval Rank and Typology

Rank	Typology	Description
1	Major Global Force Projection Navy (Complete)	Navy capable of carrying out all the military roles of naval forces on a global scale. It possesses the full range of carrier and amphibious capabilities, sea control forces, and nuclear attack and ballistic missile submarines, and all in sufficient numbers to undertake major operations independently. E.g., United States.
2	Major Global Force Projection Navy (Partial)	These are navies that possess most if not all of the force projection capabilities of a "complete" global navy, but only in sufficient numbers to undertake one major "out of area" operation. E.g., Britain, France.
3	Medium Global Force Projection Navy	These are navies that may not possess the full range of capabilities, but have a credible capacity in certain of them and consistently demonstrate a determination to exercise them at some distance from home waters, in cooperation with other Force Projection Navies. E.g., Canada, Netherlands, Australia.
4	Medium Regional Force Projection Navy	These are navies possessing the ability to project force into the adjoining ocean basin. While they may have the capacity to exercise these further a field, for whatever reason, they do not do so on a regular basis.
5	Adjacent Force Projection Navies	These are navies that have some ability to project force well offshore, but are not capable of carrying out high-level naval operations over oceanic distances.
6	Offshore Territorial Defence Navies	These are navies that have relatively high levels of capability in defensive (and constabulary) operations up to about 200 miles from their shores, having the sustainability offered by frigate or large corvette vessels and (or) a capable submarine force.
7	Inshore Territorial Defence Navies	These are navies that have primarily inshore territorial defence capabilities, making them capable of coastal combat rather than constabulary duties alone. This implies a force comprising missile-armed fast-attack craft, short-range aviation and a limited submarine force.
8	Constabulary Navies	These are significant fleets that are not intended to fight, but to act purely in a constabulary role.
9	Token Navies	These are navies that have some minimal capability, but this often consists of little more than a formal organisational structure and a few coastal craft. These states, the world's smallest and weakest, cannot aspire to anything but the most limited constabulary functions.

Source: Department of National Defence. *Leadmark: The Navy's Strategy for 2020*. 2001.

Canada's future navy must thus evidently be prepared to defend Canada's sovereignty independently of other nations, but it may also operate in expeditionary missions in the world's littorals, and continue to seek to influence the global security agenda by remaining diplomatically engaged on the world chessboard. To that end, *Leadmark 2020* suggests the

performance of naval roles and functions based on the *use of the sea* as the unifying key as illustrated in Figure 16.[63]

Figure 16 - *Leadmark 2020* Canadian Naval Roles and Functions for the 21st Century

Source: Department of National Defence. *Leadmark: The Navy's Strategy for 2020*. 2001.

A new set of rationalized naval functions was produced inspired primarily from the *Leadmark 2020* naval roles and functions but also from other keystone documents such as the

[63] Ibid., 67

maritime tasks from the 2005 Canadian defence policy statement (see Appendix 3),[64] and Dr. Milan N. Vego's spectrum of naval activities published by the Joint Military Operations Department at the US Naval War College (see Table 15).[65] These naval functions are deemed specifically tailored to capture the range of activities that a true rank 3 navy should be capable to accomplish, either independently on a routine basis in national waters or/and in the extreme with coalition forces in foreign waters (see Table 16). These functions and responses are examined as operational-level naval requirements for a fleet whose composition has not yet been determined.

[64] Canada. Department of National Defence, *Canada's International Policy Statement. A Role of Pride and Influence in the World: Defence* (Ottawa, ON: Assistan Deputy Minister (Public Affairs), 2005), 38, http://www.forces.gc.ca/admpol/downloads/Canada_Defence_2005.pdf (accessed 15 March 2011).

[65] Milan N. Vego, "On Naval Power," *Joint Force Quarterly* 3rd quarter, no. 50 (Summer 2008), 8-17.

Table 15 – US Naval Activities within the Spectrum of Conflict at Sea

Peacetime	Operations Short of War
Routine Activities • Enforcing maritime border laws and customs • Vessel traffic service • Salvage • Ordinance disposal • Hydrographic survey • Oceanographic research **Homeland Security** • Ballistic missile defense • Combating terrorism • Port security • Protecting critical installations/facilities on the coast • Counternarcotics (drugs) • Intercepting illegal immigration • Countering weapons smuggling • Combating piracy • Countering environmental pollution **Protection of the Country's Economic Interests** • Protecting commercial shipping • Protecting fisheries • Protecting offshore oil/gas installations • Protecting seabed mineral deposits • Combating piracy **Enforcement of International Maritime Treaties and UN Resolutions on Combating Transnational Terrorism** • Non-proliferation of WMD • Ensuring freedom of navigation/overflight • Intercepting illicit arms trade • Combating piracy • Eliminating human trafficking **Humanitarian Assistance/Disaster Relief** • Assistance in the aftermath of natural disasters • Emergency medical assistance • Goodwill activities • Refuge assistance • Civilian evacuation	**Support of Foreign Policy** • Coercive diplomacy • Naval diplomacy • Crisis prevention/management • Maritime border disputes **Support of Military (Theater) Strategy** • Nuclear deterrence • Conventional deterrence • Ballistic missile defense • Security cooperation **Support of Peace Operations** • Peacekeeping operations • Peace enforcement operations • Expanded peacekeeping operations/peace enforcement **Low-Intensity Conflict** **Support on Insurgency Campaign** **Support of Counterinsurgency Campaign** **Support of Counterterrorism Campaign** **High-Intensity Conventional Conflict** **Regional War** **Global war**

Source: Vego, Milan N. "On Naval Power." *Joint Force Quarterly* 3rd quarter, no. 50 (Summer 2008): 8-17.

Table 16 - Operational-Level Naval Functions

Naval Function	Description
Air and Maritime Search and Rescue (SAR)	The use of aircraft, surface craft, submarines, specialised rescue teams and equipment to search for and rescue personnel in distress on land or at sea.
Humanitarian Assistance	Emergency civil assistance undertaken in response to natural or human-induced disasters such as a flood, earthquake, tornado, ice storm, hazardous material or CBRN incident, and oil spill.
Assistance to Law Enforcement Agency	Support law enforcement agency operations such as response to terrorist threat or attack, drug-interdiction, security and control, and aid to civil power.
Fisheries Patrols	Assist the DFO and the Canadian Coast Guard to combat poaching and foreign overfishing within Canada's EEZ.
Sovereignty Patrols	Provide armed sea-borne surveillance, presence, security and control of Canadian territory and air/maritime approaches. Deter threats to domestic and commercial shipping.
Arctic Sovereignty Patrols	Provide armed sea-borne surveillance, presence, security and control of Canadian Arctic territory and air/maritime approaches. Deter threats to domestic and commercial shipping.
Maritime Interdiction Operations (MIO)	The surveillance, interception and, if necessary, boarding of commercial vessels to verify, re-direct or impound their cargoes in support of the enforcement of economic sanctions.
Non-combatant Evacuation Operations (NEO)	Operation to relocate to a place of safety non-combatants threatened in a foreign country.
Littoral Maritime Force Projection	Ability to project, sustain and apply effective military force from the sea in order to influence events on land. Support to forces ashore (STFA) including sea lift, sea basing, and naval fire support direct/indirect fire.
Standing NATO Response Force Maritime Group 1 (SNMG1)	Train with, participate in and/or lead the Standing NATO Response Force Maritime Group 1.[66]
US Task Group	Train with, participate in and/or provide escort for a United States Task Group, e.g. Carrier Battle Group (CVBG), Expeditionary Strike Group (ESG), Carrier Strike Group (CSG), or Marine Expeditionary Unit (MEU).

Source: Adapted from Department of National Defence. *Leadmark: The Navy's Strategy for 2020*. 2001.

The naval functions are mapped to both the domestic and expeditionary operational-level military activities thus establishing the maritime contribution to CF operations. The impact question was how critical is the ability to complete a given operational-level naval function in

[66] Rob Huebert, "Continental Defence at Sea - the Canadian Challenge," *Journal of Military & Strategic Studies* 9, no. 2 (Winter 2007), 7, http://www.jmss.org/jmss/index.php/jmss/article/view/113/124 (accessed 1 March 2011).

contributing to a given CF operational-level military activity? The voting results in Figure 17 show that conducting sovereignty patrols and assisting law enforcement agencies were the naval functions most contributing to all CF military activities, followed very closely by conducting air and maritime SAR. The frequency question was how likely is a given operational-level naval function be used or required to contribute to a given CF operational-level military activity, in the event that activity occurs? The voting results in Figure 18 show that conducting sovereignty patrols is the naval function most likely to be required followed by providing humanitarian assistance.

The overall effect of a given operational-level naval function in contributing to a given CF operational-level military activity, when considering both the impact and frequency, is illustrated in Figure 19. The SP2 voting results show that conducting sovereignty patrols was the most effective naval function. Assisting law enforcement agencies and conducting maritime interdiction operations alternated for second position depending on whether or not the relative importance of the military activities was weighted.

Weighing the naval function's effect does not radically change their relative effect. As in the previous mapping, the weighting is propagated to the military roles, in other words, it is that of the military activities effect on the weighted military missions' effect on the military roles. As a matter of fact, the groupings of functions are reduced from four to three when comparing the normalized to the minimum. The naval functions most effective in both cases are "assistance to law enforcement agencies," "sovereignty patrols," and "maritime interdiction operations." The least effective functions in both cases are "fishery patrols," and "arctic patrols." This is not to say that said functions are not important, but when compared to the aforementioned functions, they do not have an "across-the-board" effect. Their specificity therefore limits their overall

impact on the military missions and roles. This mapping facilitates the evaluation of the MOE for the CF operational-level domestic and expeditionary activities. Of note, the mappings up to now corresponded to a top-down analysis; henceforth a bottom-up examination follows.

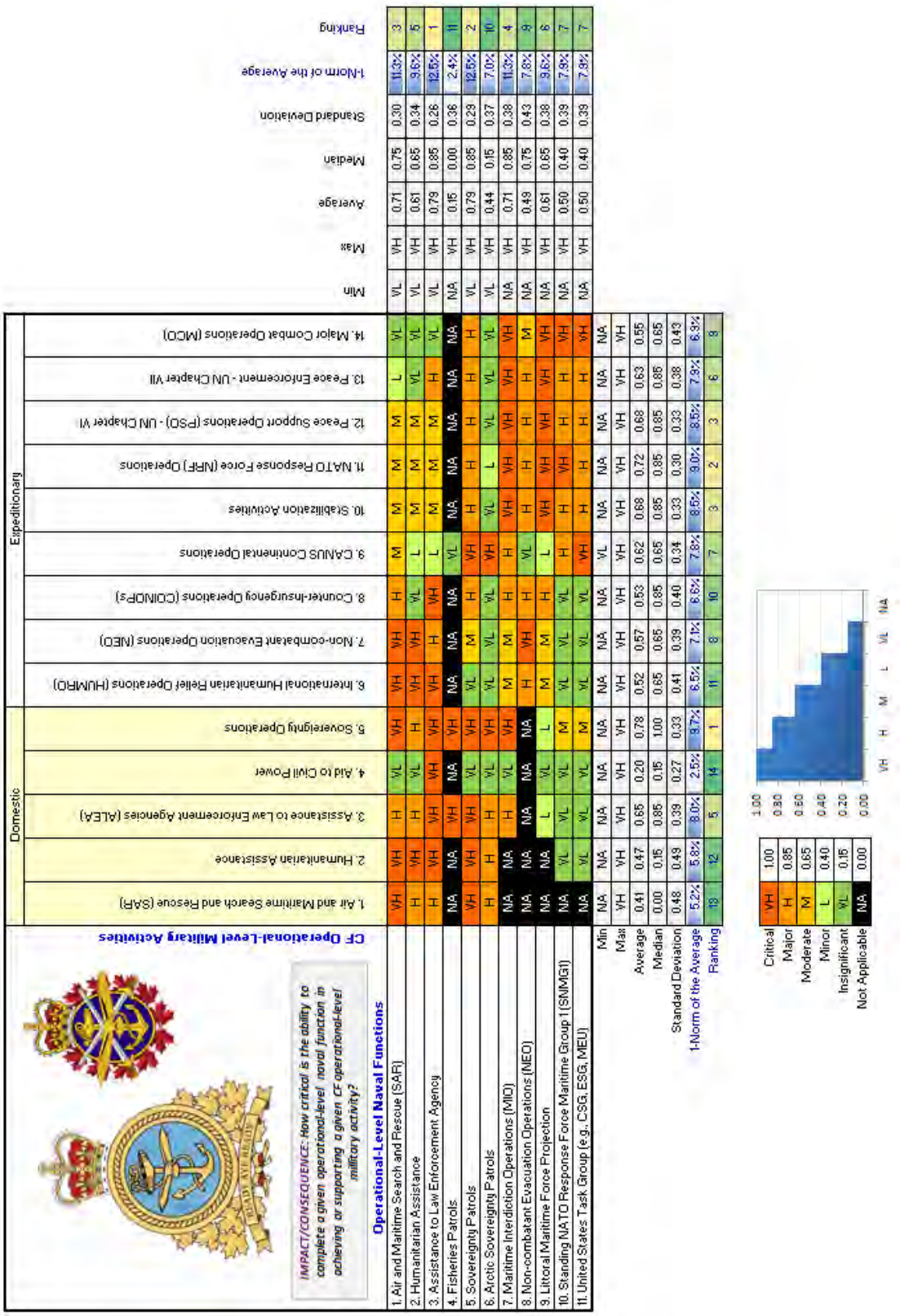

Figure 17 – Impact Assessment of Naval Functions and CF Activities

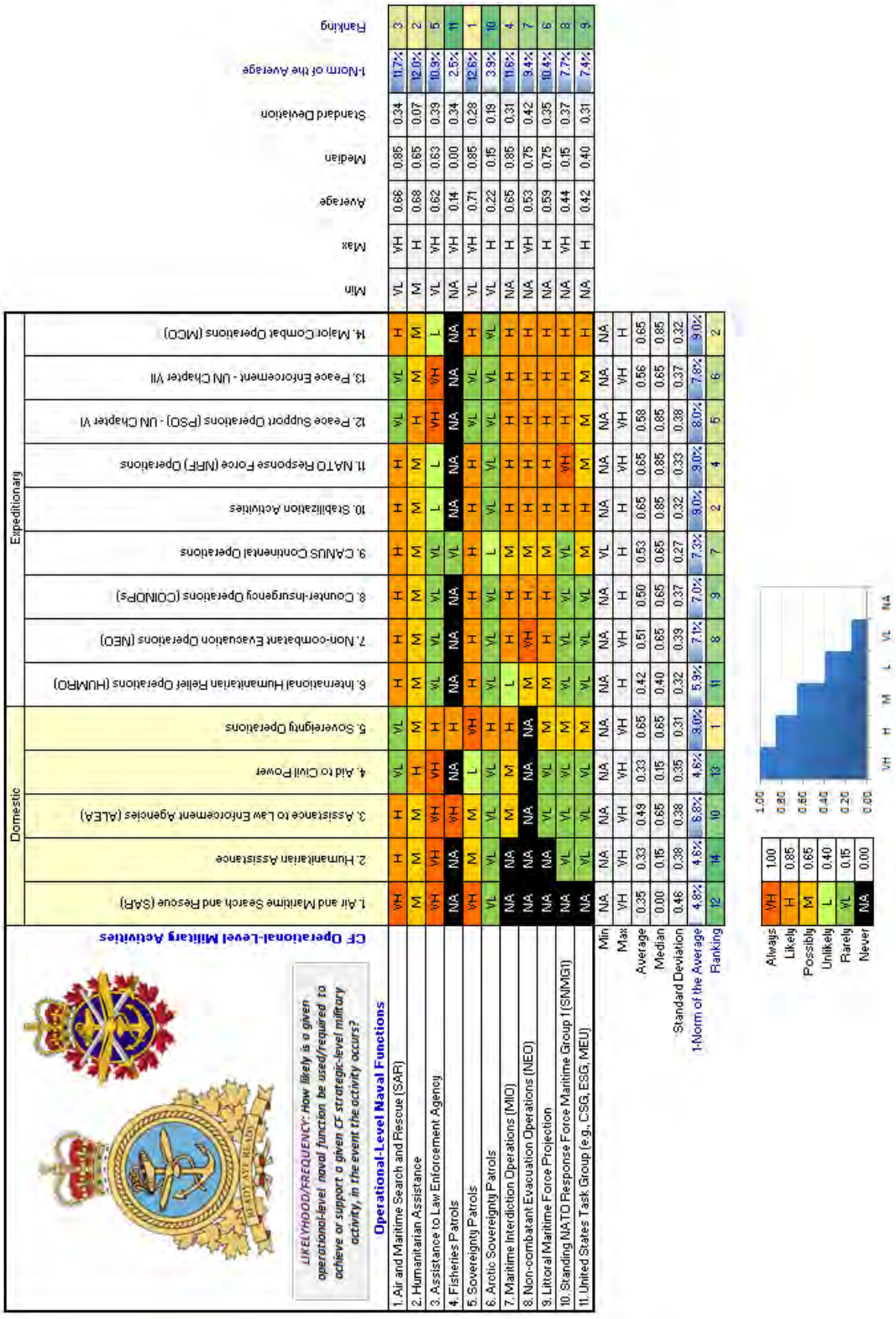

Figure 18 – Frequency Assessment of Naval Functions and CF Activities

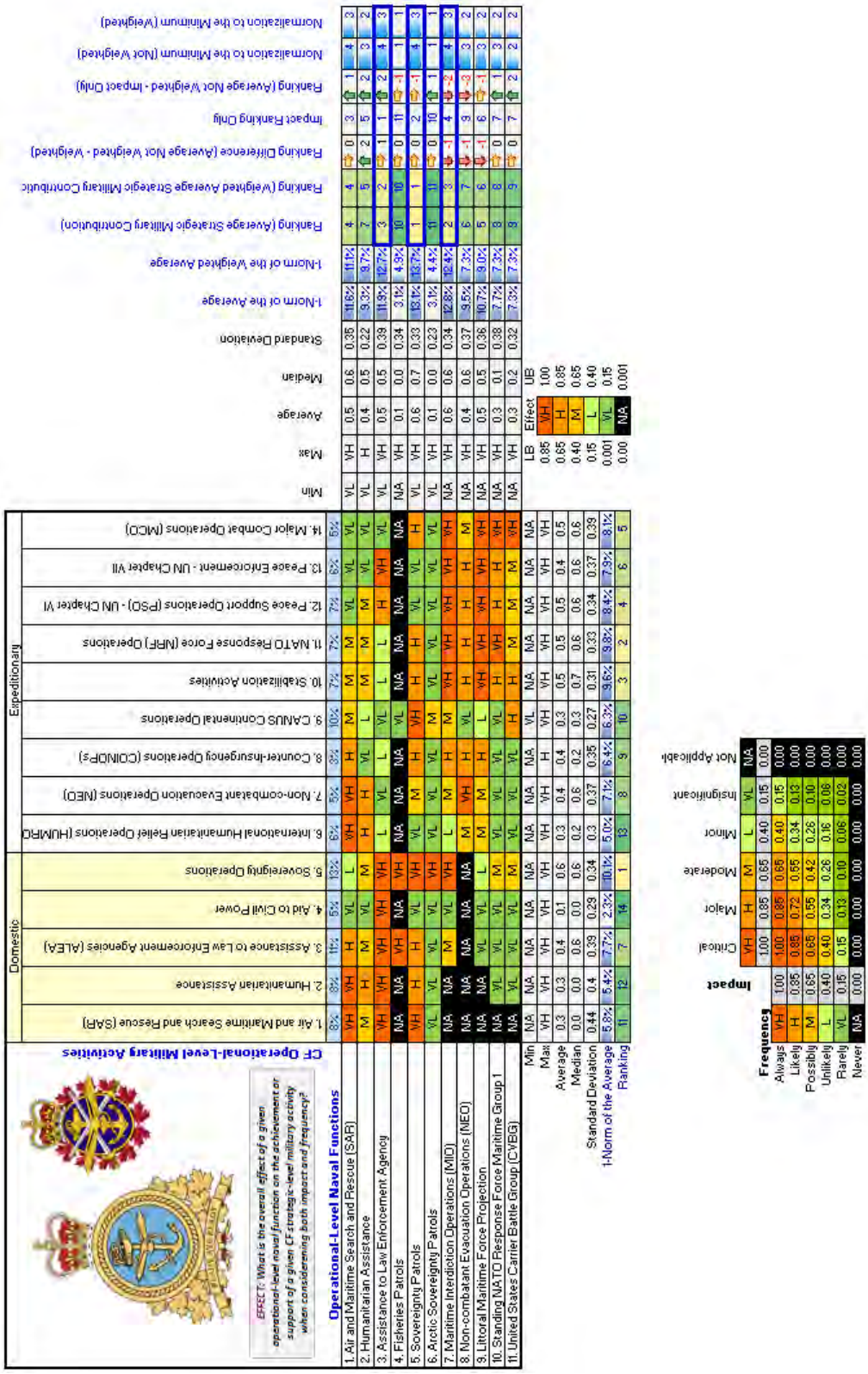

Figure 19 – Overall Effect Analysis of Naval Functions and CF Activities

SHIP CAPABILITIES AND NAVAL FUNCTIONS

Operational-level naval functions, which may be performed by a single ship independently or as part of a task group, can be further linked to a set of ship's capabilities denoting the ability to act and create a net operational effect.[67] The ship's capabilities correspond to design parameters, and the level of ship's capability corresponds to the measure of performance (MOP) of that design parameter. These design parameters are key user requirements selected on merit because they are critical to the achievement of the operational needs; they identify the essential core characteristics of the user need, and they are of particular interest to management.[68]

At the tactical level, naval forces operate in a three-dimensional field captured by the selected multidisciplinary ship capabilities and their associated non-linear levels shown in Appendix 4 and summarised in Table 17. The first mapping established the relative importance of the ship's capabilities to the naval functions. The question was what impact not achieving the required capability level have on a given operational-level naval function? The voting results in Figure 20 show that C4I and organic air disputed first and second place, whereas boarding and maximum sustained speed alternated third and fourth place, as the capabilities most contributing to all naval functions, depending on whether or not the relative importance of the naval functions was weighted.

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[67] C. Eisler, A. Bourque and W. Reive, *Fleet Mix Study: Capability Supply and Demand Requirements for Iteration II (TM 2009-040)* (Ottawa, ON: Defence Research and Development Canada (DRDC), Centre for Operational Research and Analysis (CORA), September 2009).

[68] UK Ministry of Defence (MOD), "Key User Requirements (KUR) Principles," in *Policy, Information and Guidance on the Requirements and Acceptance Aspects of UK MOD Defence Acquisition*, ed. Acquisition Operating Framework (AOF), 1.0.3 ed. (Norwich, UK: Her Majesty's Stationery Office's (HMSO), October 2010), http://www.aof.mod.uk/aofcontent/tactical/randa/content/kurprinciples.htm (accessed 20 January 2011).

Table 17 – Ship's Capabilities

Domain	Capability
Combat	Anti-Air Warfare (AAW)
	Anti-Surface Warfare (ASuW)
	Anti-Submarine Warfare (ASW)
	Mine Warfare
Support	Boarding
	Naval Fires Support
	Command and Control, Communications , Computers, Intelligence (C4I)
	Organic Air
	Seabasing and Sealift
Engineering	Maximum Sustained Speed
	Range
	Endurance
	Transit in Polar Ice Conditions
	Survivability

The next mapping established the criticality of a given tactical-level ship's capability in achieving or supporting a given operational-level naval function? More explicitly, the question sought to identify the minimum threshold level required by a given ship capability in order to conduct a given naval function such that the operational and strategic expectations of CFDS and military doctrine be satisfied? The voting results in Figure 21 show that boarding, organic air, maximum sustained speed and ASuW are the capabilities most effective to all naval functions.

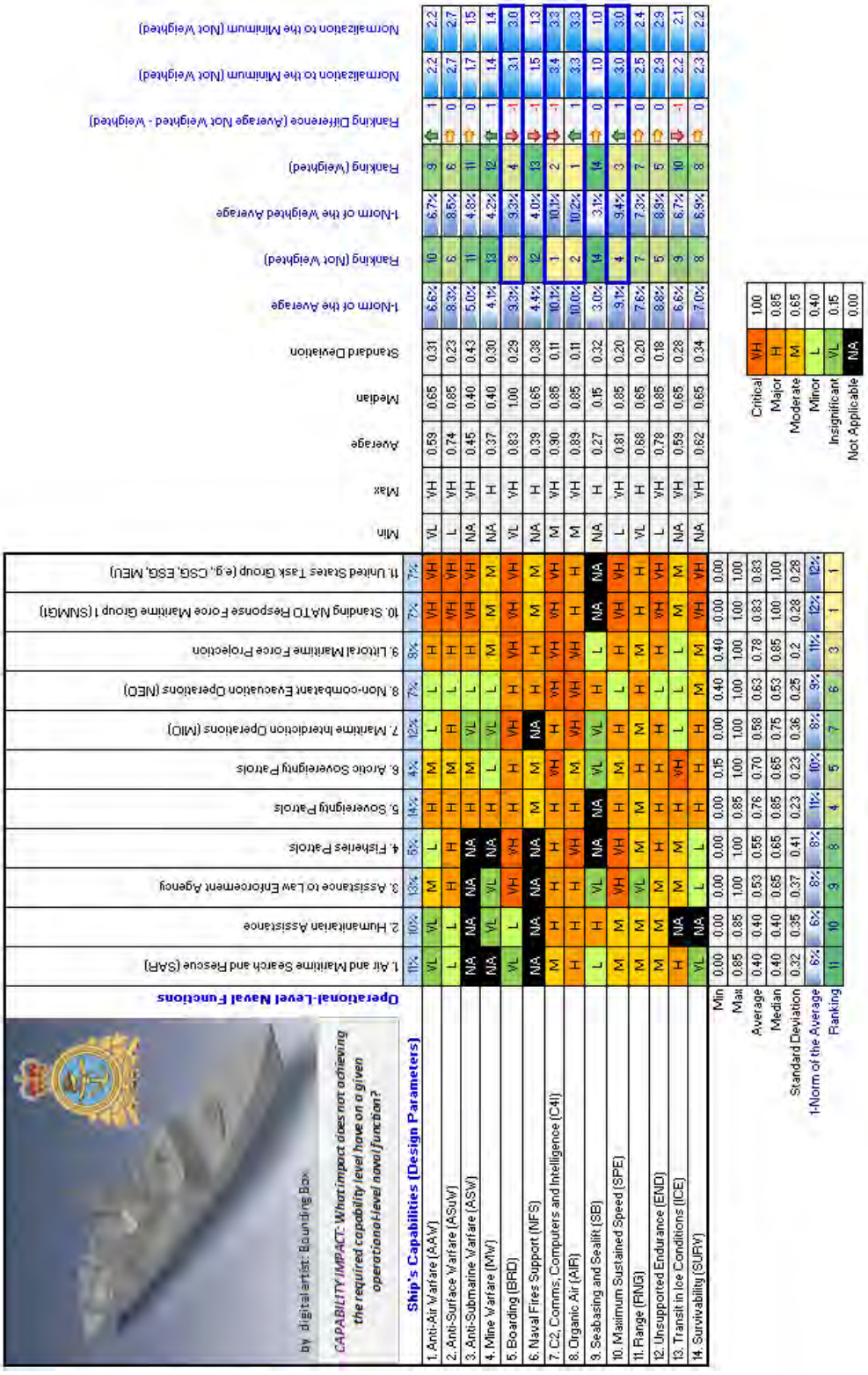

Figure 20 – Impact Assessment of Ship's Capabilities to Naval Functions

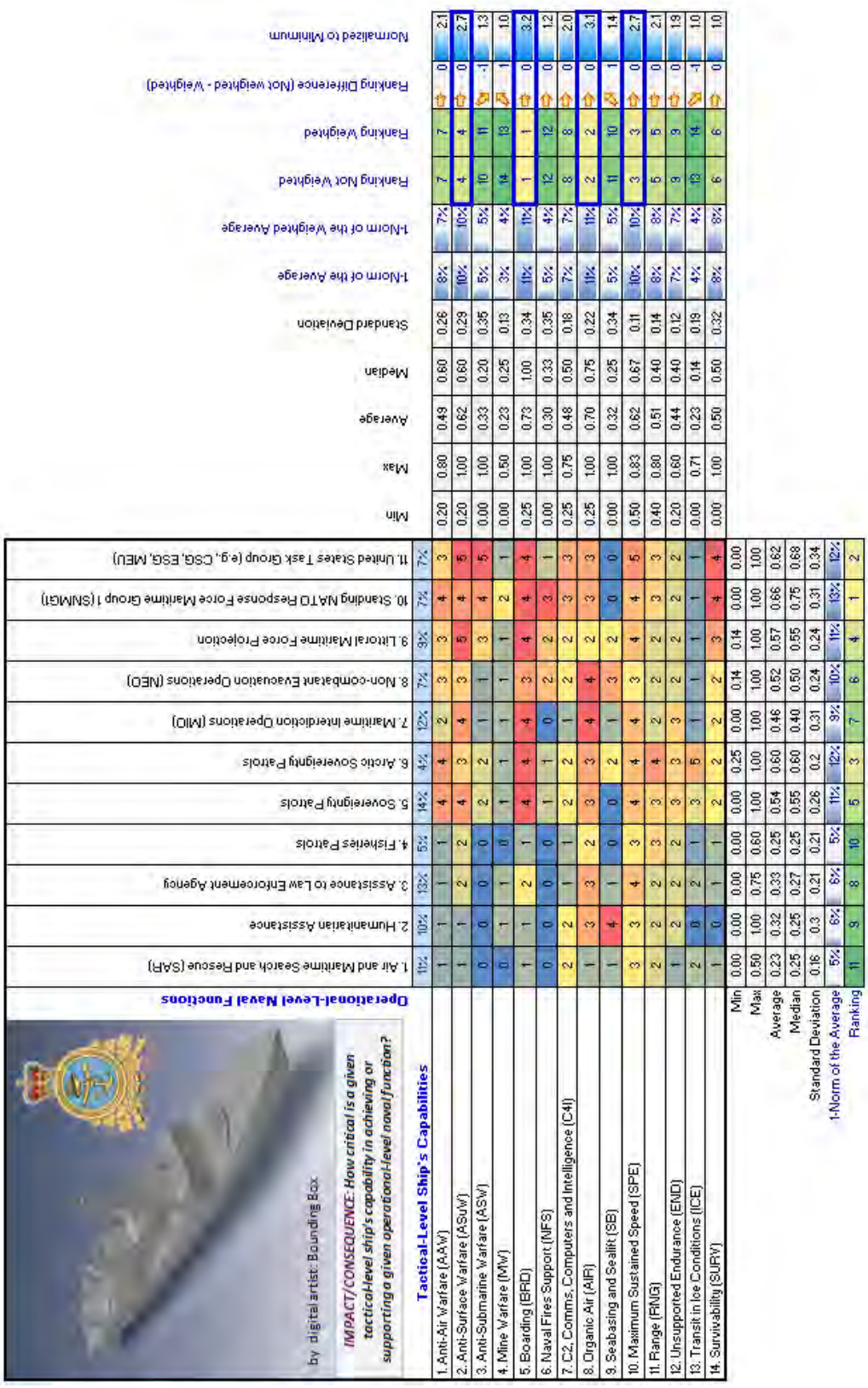

Figure 21 – Threshold Ship's Capability Levels

SYNTHESIS AND VISUALIZATION

The results from the SP2 voting are synthesized into a portable decision-making support tool as shown in Figure 22 allowing operators and technical staff to perform interactive trade studies and dynamically visualize the outcomes. The SP2 tool is an example of a rational decision-making support tool that also embraces the principles of intuitive reflection within its construction. Rational decision-making is thought to be straightforward: first define the problem, then diagnose its causes, next develop possible solutions, and finally select the best option and implement the decision. Ship design is, however, rarely that simplistic in that not all alternatives can possibly be known, most external factors can neither be controlled nor managed, and consequently all critical issues are truly difficult to forecast. In these cases, a utopian solution will not emerge; instead, the decision-makers must rely on a model that provides solutions that are "good enough" with respect to fitness of purpose.[69] There is therefore the need to support the exploration of "what if" scenarios that will enable team members to collectively create a shared picture that conveys everyone's concerns and opinions whilst minimizing premature consensus.[70]

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[69] Herbert A. Simon, "Rational Decision-Making in Business Organizations," *The American Economic Review* 69, no. 4 (September 1979), 493-513.

[70] Johansson and others, *Knowledge Maturity as a Means to Support Decision Making during Product-Service Systems Development Projects in the Aerospace Sector*, 41.

Figure 22 – SP2 Visualization showing a Medium Regional Force Projection Navy Rank 4

By adjusting the ship's capability levels based on systems attributes (i.e., the design parameter MOP), the user establishes the selected naval functions' MOE to achieving sufficient *sea control*, depending on the scenario examined. Sea control is defined as the condition in which one has freedom of action to use the sea for one's own purposes in specified areas and for specified periods of time and, where necessary, to deny use to the enemy.[71] The user can thus more effectively evaluate the ship capability levels required to satisfy either the low-intensity or the high-intensity naval functions and also see the contribution to domestic and expeditionary

[71] Canadian Forces College, *Naval Doctrine Manual*, C-1.

CF operational-level activities. In turn, the user can visualize and assess the maritime contribution to strategic-level military missions and geopolitical-level aspirations.

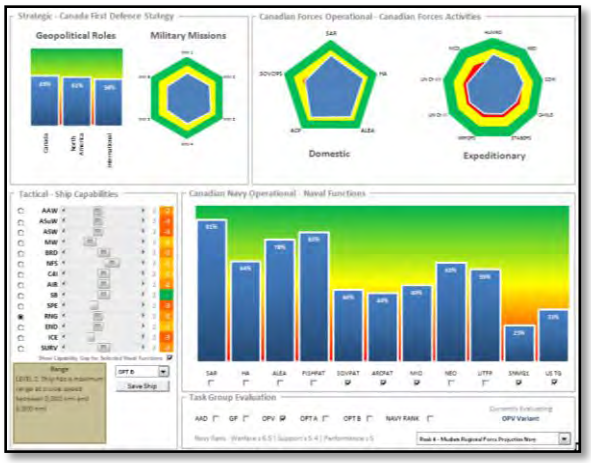
Ship capability levels were also preassigned to all nine navy ranks and also generic area air defence (AAD), general purpose (GP) and offshore patrol vessel (OPV) designs in order to increase the "what if" scenario possibilities (see Figure 23). In doing so, the user can thus compare user-defined ship design options not only against each other, but also against individual or multi-ship combinations of AAD, GP and OPV designs, or against a given navy rank task group. The SP2 tool can show not only where there are shortcomings in capabilities but also where there is excess capability in performing a given naval function.

As espoused by the "seeing first" decision-making approach, visualization allows team members to see the influence of an individual or collective action on the whole project through all hierarchical levels of abstraction.[72] Visualization generates necessary discussions challenging team members' perceptions and knowledge. It also facilitates the collective shaping necessary for unity of purpose and a common language between technical staff, operators, senior management, and politicians. The usefulness of the SP2 process will be elaborated in the next chapter with several "what if" scenarios.

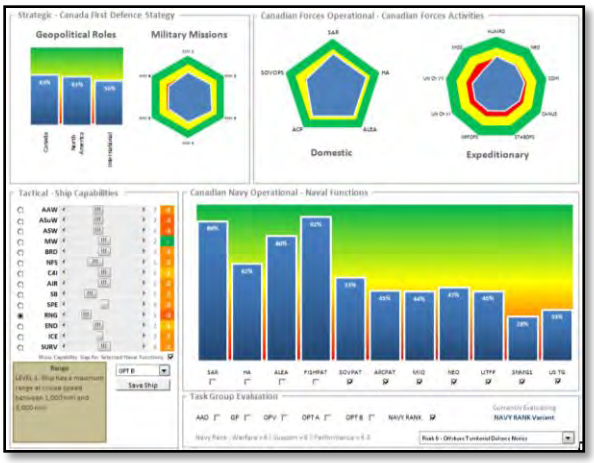
[72] Henry Mintzberg and Frances Westley, "Decision Making: It's Not what You Think," *MIT Sloan Management Review* 42, no. 3 (Spring 2001), 89-93.

AAD Variant

GP Variant



OPV Variant



Rank 6 Navy

Figure 23 – SP2 Visualization of AAD, GP and OPV Variants and Rank 6 Navy

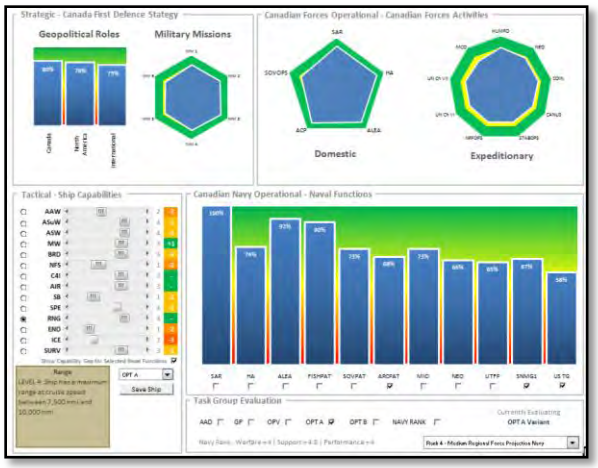
CHAPTER 3 – FLEET CONSTITUTION AND SHIP VARIANTS

UNDERSTANDING THE STATUS QUO – RANK 3 NAVY

Leadmark's placement of Canada as a rank 3 medium global force projection navy is claimed neither to be arbitrary nor inconsistent with the station Canada holds in the world. *Leadmark* further attributes this relatively high ranking to the capabilities resident in the Canadian navy and the demonstrated willingness of the Canadian government to deploy it abroad.[73] In the meantime, the CFDS established the roadmap so that the next generation navy will continue to monitor and defend Canadian waters and make significant contributions to international naval operations. This stance begs the question on how to validate if Canada's naval capabilities truly correspond to that of a rank 3 navy with more confidence.

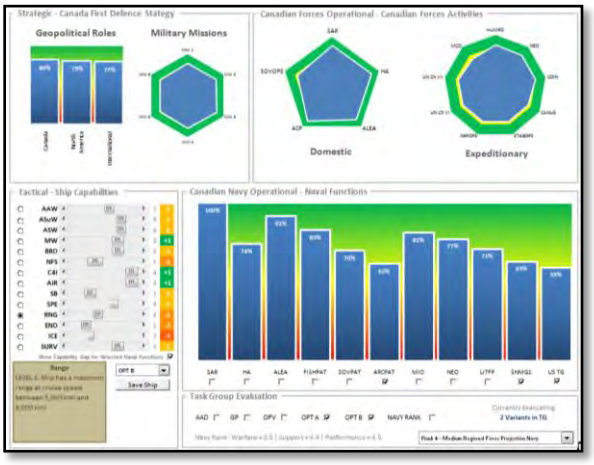
To that end, the SP2 process can assist in better understanding the status quo before moving forward. Figure 24 shows the SP2 visualizations for an individual Halifax-Class frigate, an Iroquois-class destroyer, a task group composed of Halifax-Class frigates and Iroquois-class destroyers, and a rank 3 medium global force projection task group. When compared to Figure 22, one can see that a Halifax-Iroquois task group would fall in between a rank 4 and a rank 3 navy in terms of capability. If that task group would be supplemented by one AOR vessel and a conventional submarine, there is no doubt that the added range, endurance and underwater warfare capabilities would make a typical Canadian naval task group akin to that of a capable rank 3 navy, speaking strictly in terms of capability.

[73] Canada. Department of National Defence, *Leadmark: The Navy's Strategy for 2020*, 47.



Halifax-Class Frigate

Iroquois-Class Destroyer



Halifax-Iroquois Class Task Group

Rank 3 Navy Task Group

Figure 24 – Canadian Navy Ships and Rank 3 Navy Task Group

It must however be reminded that a rank 3 navy must have a credible capacity in certain capabilities, and more importantly, must consistently demonstrate a determination to exercise them at some distance from home waters, in cooperation with other force projection navies. Task group effectiveness is a matter of not only combined capabilities but also capacity and readiness. Capacity refers to the number of ships necessary for credible force projection; quantity is often a quality in the military domain. Capacity also supports readiness, that is, the

resources associated with material availability, logistic support, and human capital to sustain prolonged operations or several rotations of ships in a naval campaign.

This example showed how quickly the SP2 process can evaluate the status quo so that decision-makers can move forward with a higher degree of confidence in their initial assumptions. This example however highlighted that the SP2 process does not directly account for capacity, that is, the number of ships within a task group. The SP2 decision-making support tool will next be used to explore how the CFDS foresees keeping Canada's rank 3 navy status with a fleet of *common hull design* ships.

COMMON HULL DESIGN

The CFDS stipulates that "while all these vessels will be based on a *common hull design*, the frigate and destroyer variants will be fitted with different weapons, communications, surveillance and other systems."[74] This statement implies that a single surface combatant design is envisaged with a common hull form, propulsion and power plant, and core equipment fit. This baseline configuration would be complemented with open-architecture engineering and modularity of armament, sensors and electronics, wherever feasible, to tailor a ship configuration to specific missions or general-purpose duties.[75] The demand for a versatile, flexible and upgradeable general-purpose ship is far from innovative. In fact, the 1971 White Paper on Defence, *Defence in the 70s*, embraced the same principle.

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[74] Canada. Department of National Defence, *Shaping the Future of the Canadian Forces: A Strategy for 2020*, 17.

[75] Scott C. MacKenzie and Rohit Tuteja, *Modular Capabilities for the Canadian Navy's Single Class Surface Combatant: A Perspective on Flexibility (CR 2006-004)* (Ottawa, ON: Defence Research and Development Canada (DRDC), Consulting and Audit Canada, February 2006).

> The Government believes Canada's maritime forces must be reoriented with the long term objective of providing a more versatile general purpose capability. Versatility is required because it is not possible to be certain precisely which maritime activities will be required and which will not in the years ahead. It is therefore sensible to design a general purpose capability for Canada's maritime forces.[76]

A decade of in-depth studies ensued throughout the 1970s and early 1980s. Results seemingly always gravitated around the premise that a fleet of general-purpose frigate/destroyer-type ships in the 4000-5000 tonne displacement range would best meet the sovereignty obligations as well as blue water, NATO/UN commitments.

Other nations have executed such designs. The FREMM family of multi-purpose frigate (French *Frégate multi-mission* or Italian *Fregata Europea Multi-Missione*) is one such design by the French naval defence shipbuilder DCNS/Armaris and the Italian shipbuilder Fincantieri that is capable of being configured in three different versions (AAW, ASW, and land attack general-purpose) but with similar hulls and armament. Moreover, such reconfigurable designs have also been built and successfully marketed by the German shipbuilding company Bloom + Voss with their MEKO "*Mehrzweck-Kombination*" (multi-purpose-combination) family of warships (see Figure 25).

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[76] Canada. Department of National Defence, *Defence in the 70s: White Paper on Defence* (Ottawa, ON: Information Canada, August 1971), 28, http://www.forces.gc.ca/admpol/downloads/Defence%20in%20the%2070s.pdf (accessed 15 March 2011).

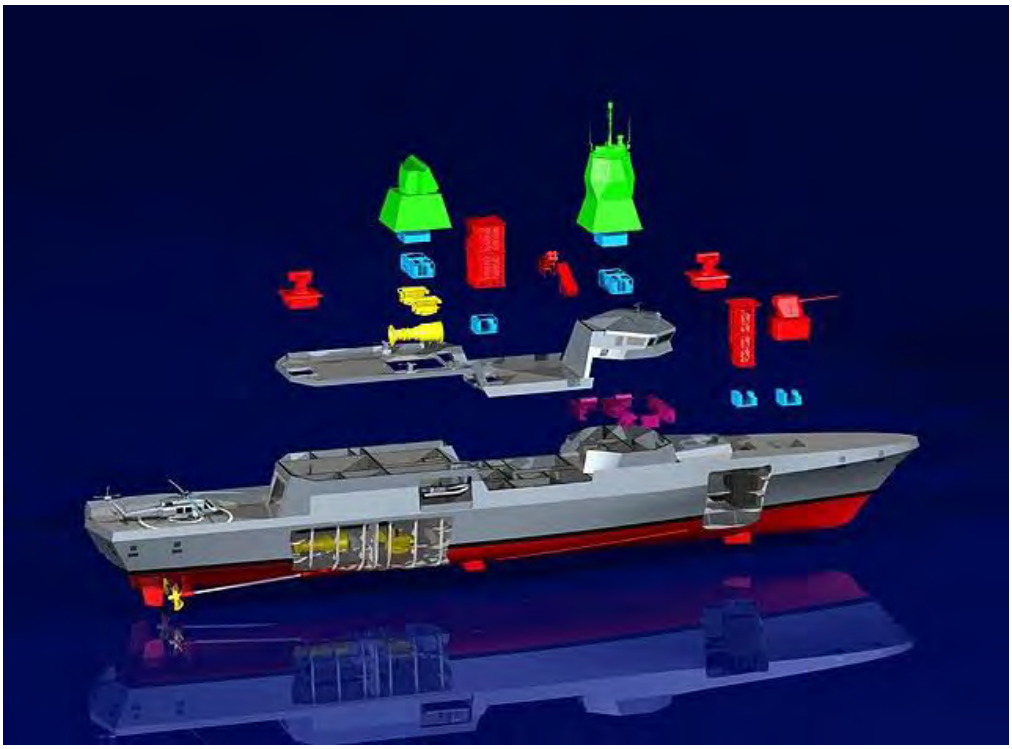


Figure 25 - Bloom + Voss MEKO Modular Design

Source: Bloom + Voss

The SP2 process is a logical tool for conducting gap analyses between ship options in order to evaluate the possible optimum designs for a given scenario. In this instance, the question is whether a single large vessel with top level expeditionary combat capabilities in AAW, ASuW, ASW, and littoral force projection as well as other capabilities dedicated to sea control and sovereignty, integrated in one common platform, is the most effective option. Maritime studies strategist, Ken Hansen (2007), argued that the emergence of asymmetric threats such as those sprung by failed and failing states makes it increasingly difficult for a single large platform to respond effectively to all the possible missions within the spectrum of conflicts. Claiming that the unpredictability of war can lead to unforeseen circumstances, Hansen

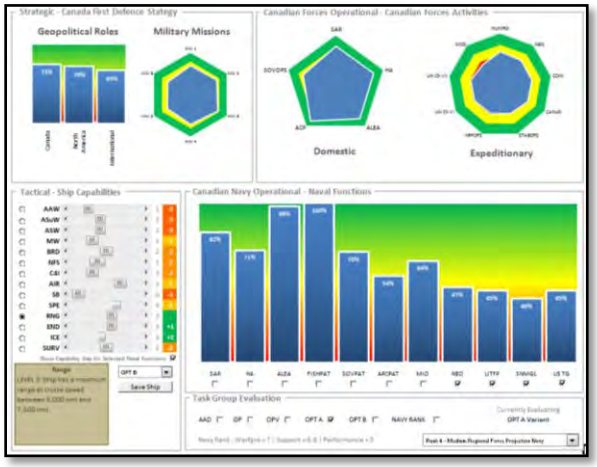
suggested that the broad range of operating conditions may require a balancing act among high-capability major warships and low-capability minor ones.[77]

This argument points towards effectively balancing domestic and expeditionary capabilities within a single ship or a task group, a task well suited for the SP2 tool. The SP2 framework developed in Chapter 2 is comprised of 11 naval functions spanning the spectrum of conflict at sea which in turn contribute to five domestic operations and nine expeditionary operations spanning the spectrum of joint and combined CF missions. The broad range of relevant naval functions and joint activities inserted in the SP2 structure therefore accounts for the plurality and unpredictability anticipated by the fog of war without computationally cluttering the model.

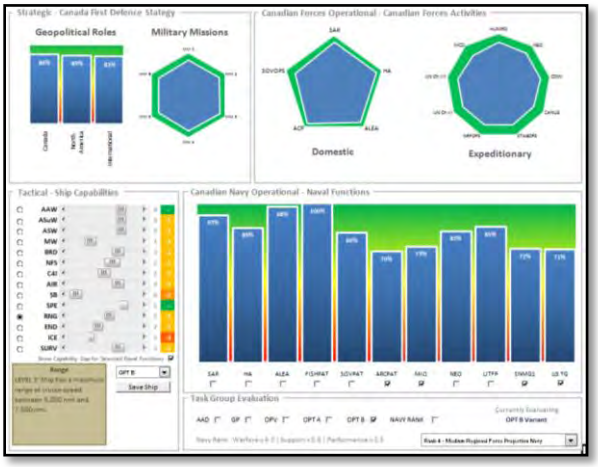
Figure 26 shows the minimum capability selections for a possible ship variant specialized in domestic operations with limited arctic sovereignty capabilities, the minimum capability selections for a possible ship variant specifically designed for expeditionary operations, a task group comprised of these two variants, and a rank 4 navy task group. Not surprisingly, the domestic design satisfactorily meets domestic requirements all the way to the geopolitical level but is marginal at continental defence and very poor at international operations, especially UN peace enforcement operations and major conflict operations. Conversely, the capabilities required to satisfactory conduct expeditionary operations subsumed, in excess, those required for domestic operations. These two variants could either be two distinct configurations of a common hull design or be two different ships within a task group. The evaluation of a task group comprised of the domestic and expeditionary designs indicates that such a combination

[77] Hansen, *The Superior-Simple Ship Fleet Construct*, 5.

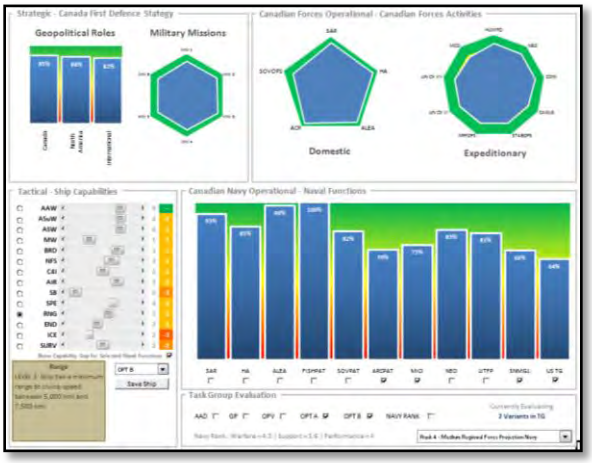
would lie somewhere between a rank 4 navy (medium regional force projection navy) and a rank 3 navy (medium global force projection navy) according to *Leadmark*'s criteria.



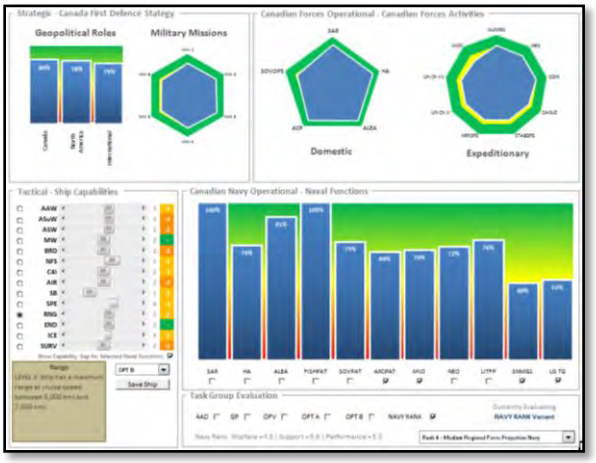
Domestic Ship



Expeditionary Ship



Domestic-Expeditionary Ships Task Group



Rank 4 Navy Task Group

Figure 26 – Domestic and Expeditionary Ships and Rank 4 Navy Task Group

Speaking in terms of capabilities, the SP2 results clearly indicate that acquiring expeditionary type ships will also satisfy domestic needs, some in excess. Given the CPF lengthy deliberations in the 1970s and early 1980s, the predictable debate is whether Canada can actually afford 15 ships of a single class of "reconfigurable" multi-purpose surface combatant, or

should the “transformed” Canadian navy fleet be composed of a balanced mix of affordable destroyers, frigates, corvettes and OPVs? To that end, further analysis can be conducted to examine the trade-offs between fleet composition, capability and affordability.

No military analyst would suggest the procurement of destroyers and frigates for the sole purpose of sovereignty protection and fisheries patrol, but the point here is that there is no longer a need to commission expensive and time consuming studies from external agencies to examine what can now be investigated dynamically using the in-house SP2 decision-making support tool. Senior military advisors could effectively use the SP2 visualization tool to graphically convey ideas and concerns to bureaucrats and politicians using a common language, thus collectively developing a shared understanding of the critical issues.

This example also highlighted that this version of the SP2 process does not directly account for cost. The cost estimating model is completed during phase 3 of the UTE process and is integrated with the SP2 and other models into a metamodel during phases 4 and 5. Having said that, the SP2 process could be used to evaluate the capabilities of a submitted ship design, or that of an already constructed modern ship design, for which cost data is available.

EXISTING SHIP DESIGNS EVALUATION

Considering for instance the capabilities of the Eilat Sa'ar 5 class multi-mission corvettes advertised as being the Israeli fleet's most advanced surface ships, and Germany’s newest K130 Braunschweig class ocean-going corvettes which, in size, armament, protection and role resemble modern ASuW frigates (see Table 18).

Table 18 – Eilat Sa'ar 5 and K130 Braunschweig Class Corvette Specifications

Class	Eilat Sa'ar 5	K130 Braunschweig
Image		
Type	Multi-mission corvette	Ocean-going corvette
Operator	Israeli Navy	German Navy
Crew	74	65
Displacement (tonne)	1,275	1,840
Length (m)	85.64	89.12
Beam (m)	11.88	13.28
Maximum speed (kt)	33	26
Range (nm)	4,000	4,000
Missiles	8 x RGM-84C Harpoon anti-ship missiles; 64x Barak surface-to-air missiles; 8 x IAI Gabriel II anti-ship missiles	4 x RBS-15 Mk.3 anti-ship missiles
Guns	20 mm Phalanx Mk 15 CIWS or Oto Melara 76 mm gun	1 x Otobreda 76 mm gun; 2 x MLG 27 mm autocannons; 2 x 21-cell RAM CIWS missile launchers
UUW	6 x 324 mm mk32 torpedo tubes for ATK mk46 torpedoes	Mine laying capability
Aircraft	Helipad and hangar for AS565 Panther, Kaman SH-2F or Sikorsky S-76N helicopter	Hangar for two Camcopter S-100 helicopter UAVs; helipad large enough for Sea Kings, Lynx or NH-90s helicopters
Unconfirmed Cost per Ship (not from source)	US$260 million (1993)	€208 million (2008)

Source: www.naval-technology.com

Figure 27 shows the aggregated capabilities of these two ships, their effectiveness in completing naval functions and their contributions to operational-level joint activities and strategic goals. Such a design is a salient example of the SP2 bottom-up approach providing a possible "good enough" solution at the geopolitical and strategic levels. Furthermore, it can be seen that this design would amply meet domestic naval functions especially if OPVs, AOPS and Coast Guard vessels would supplement for sovereignty and arctic patrols. Likewise, this design would adequately meet the expeditionary requirements for humanitarian relief operation (HUMRO) and non-combatant evacuation operation (NEO) joint activities. The SP2 results also highlighted the possible shortcomings with respect to the SNMG1 and US task group naval functions which could be remedied by procuring a few high-value AAD destroyers if deemed necessary for strategic clout. Considering the complexity and scope of ship design, achieving optimization in all criteria would either be a utopian solution destined to failure or disproportionately cost-prohibitive. Good enough is sometimes good enough.

Figure 27 – Eilat Sa'ar 5 and K130 Braunschweig Class Corvettes Capabilities

This example illustrated the agility of the SP2 decision-making support tool in examining existing designs for which cost data is available in an attempt to produce a cursory cost-capability study. In this scenario, the SP2 results provided insights into a uniform fleet of affordable multi-purpose corvettes potentially good enough should the strategic goals and geopolitical aspirations not be to become a worldwide large navy but rather make one's existing and modestly expanding force more effective, efficient, deadly and competent.[78] But what if the strategic context changes?

[78] Segal, *Beyond the Celebration: The Next Naval Century*

STRATEGIC STABILITY AND RELEVANCE

Ken Hansen (2007) cautioned that "if the strategic context is stable and only one or two closely related functions are called for, then a uniform fleet structure is adequate, but only so long as that condition persists."[79] It follows then that if the strategic context is complicated, changing, or uncertain, a diversified fleet structure is required. In examining the stability of the Canadian grand strategy, Brooke Claxton is evoked. As the Minister of National Defence in 1947, he wrote that "the missions of the Canadian Forces are to defend Canada, to defend North America with the United States, and after that we can choose whatever we want to do."[80] Since then, these canons have not changed much judging from the White Papers on defence promulgated since 1964 as seen in Appendix 5, and reaffirmed in the 2008 CFDS. These three priorities were captured as overarching geopolitical roles in the SP2 decision support tool and their stability and relevance can thus be assessed through multitudes of "what if" scenarios.

Taking for example the fictional scenario where a drastic change in government causes the strategic focus to divert from coastal defence and hemispheric security to defending Canada's interest by being engaged internationally. At the tactical level, what are then the optimum capabilities to effectively project force in a post 9/11 era wherein the navy is extensively asked to fight regional wars in foreign littoral waters or provide international humanitarian assistance. The SP2 process' ability to link the political goals and tactical capabilties using both the top-down approach and more importantly in this case the bottom-up approach makes it a rational tool for conceiving a platform leveraging the *manoeuvre warfare* principles of war for littoral

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[79] Hansen, *The Superior-Simple Ship Fleet Construct*, 4.

[80] Douglas Bland, "Everything Military Officers Need to Know about Defence Policy-Making in Canada," in Canadian Strategic Forecast 2000: Advance or Retreat? Canadian Defence in the 21st Century (Toronto ON: Canadian Institute of Strategic Studies, 2000), 28.

operations. From the bottom-up approach, the exercise is to adjust the ship's capabilities such that the naval function of littoral force projection be optimized as shown in Figure 28.

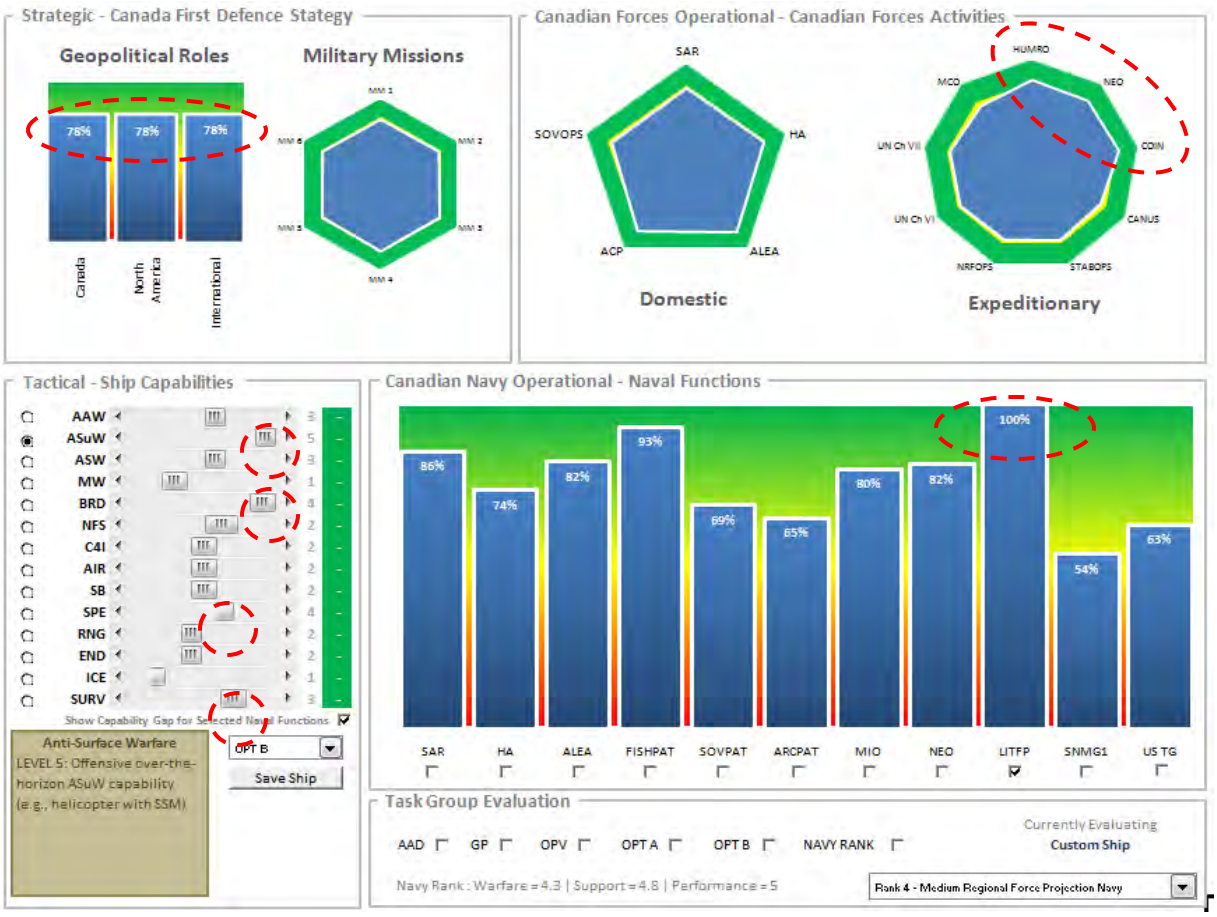

Figure 28 – Littoral Force Projection Ship Design

Figure 28 shows that at the tactical-level, a vessel optimized for the littoral force projection naval function would require high survivability features attributable to construction to naval rules; top level over-the-horizon ASuW capabilities; a maximum sustained speed greater than 27 knot; and the ability to conduct night time opposed naval boarding operations in high sea sates. At the joint operational level, the SP2 results confirm the adequacy and relevance of the tactical level assumptions (and intuition) by highlighting that such a ship design would be

optimized for counter-insurgency operations (COINOPS), NEO and HUMRO; the types of operations crucial to regional conflicts in foreign littorals. At the strategic and geopolitical level, this ship design would satisfy not just the government's current taste but also all other possible strategic goals.

This example shows the versatility and robustness of the SP2 process in using the bottom-up approach to evaluate ship designs caused by changing political aspirations. Aware of the new critical ship's capabilities, the operators and technical staff can now better focus research and development at the systems levels. For instance, tactics, techniques and technologies from foreign inshore navies like those of Israel, Germany and the Scandinavian countries can be exploited to accelerate competence in littoral operations or adapted accordingly to design swift, seaworthy, highly adaptable and low-cost high-speed vehicles better suited to tackle assymetric threats.[81] The cost-effectiveness technology of unmanned aerial vehicles (UAVs), the search and attack systems necessary to repel swarms of small combatants, and the ever present danger of the mines and quiet enemy submarines are only a few tactical considerations which should not be dismissed when designing such modern ships.[82] This example also highlighted the fact that the navy must be responsive to changes in government which may impact naval doctrine and the application of the maritime forces.

[81] Hughes, *Implementing the Seapower Strategy*, 56.

[82] Ibid., 55

MODERN NAVAL DOCTRINE AND FLEET COMPOSITION

Fleet composition and the application of the principles of war in naval affairs have been studied by naval writers and thinkers for the better part of the last century. The works of British naval theorists, Admiral Sir Herbert William Richmond, and Sir Julian Stafford Corbett are still instructive. Corbett specified in 1911 that the constitution of fleet is characterized by the grouping of its ships in accordance with the primary function each class is designed to serve.[83] He further stipulated that "the class of ships which constitute a fleet are, or ought to be the expression in material of the strategic and tactical ideas that prevail at any given time, and consequently they have varied not only with the ideas, but also with the material in vogue."[84]

To support this proposition, an extract from the results of a public domain literature survey of existing worldwide surface ships is exhibited in Appendix 6. Figure 29 shows how these ships' classifications behave differently when analyzing the data set in terms of displacement (tonne) and maximum sustained speed (knot). Not surprisingly, destroyers and frigates fulfill a different purpose than corvettes and OPVs. Moreover, destroyers and frigates are more specialized whereas corvettes and OPVs are generally more versatile based on the range of speed and design. Figure 29 is backwards looking in that it depicts how ships were previously categorized, namely in term of their dimensions (displacement, length, beam, draught) going for instance from cruisers, destroyers, frigates and corvettes in descending order. The underlying assumption here is that the heavier the displacement the more combat capable and effective is the ship. But is this approach sound and true nowadays?

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[83] Julian S. Corbett Sir, "Theory of the Means - the Constitution of Fleets," in *Some Principles of Maritime Strategy* (Annapolis, MD: Naval Institute Press, 1988 (1911)), 107-127.

[84] Ibid.

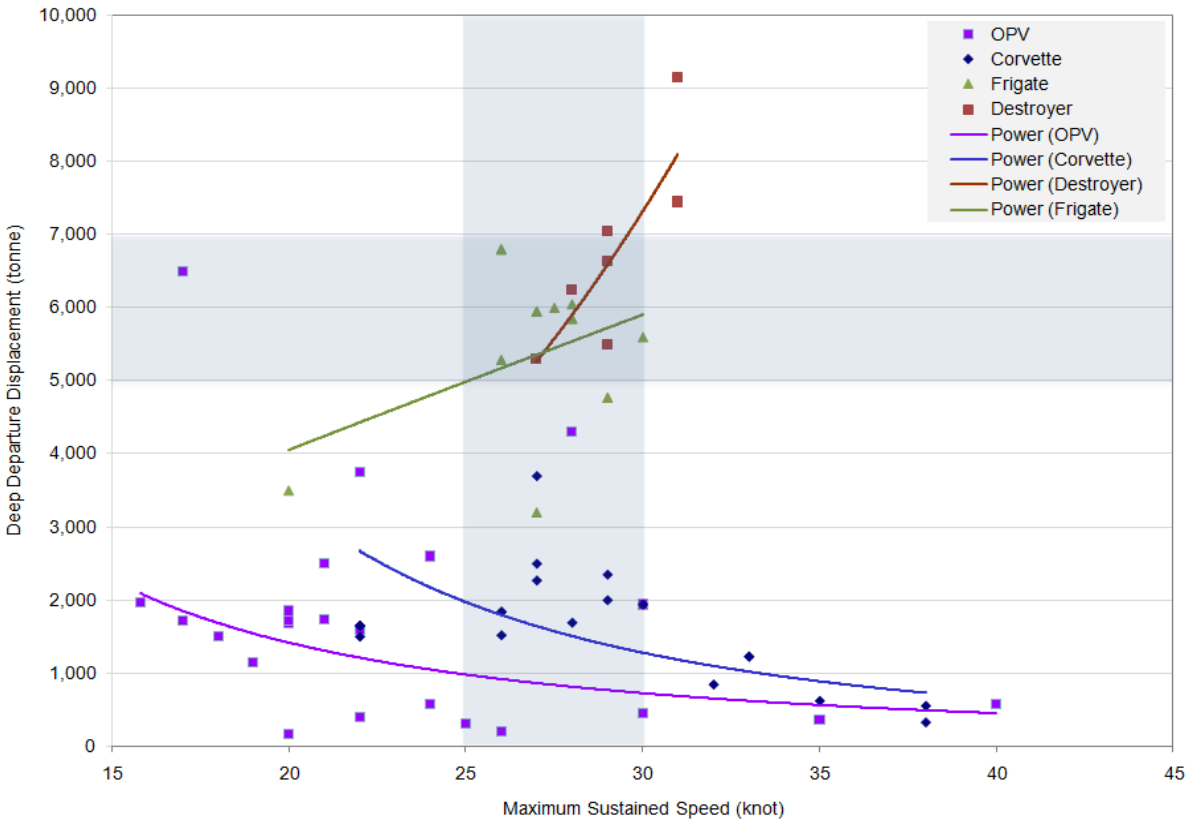

Figure 29 – Ships Displacement (tonne) vs Maximum Sustained Speed (knot)

The culmination of the "what if" scenarios examined in this chapter may have provided the catalyst for a new approach to conceptual design and its effect on naval warfare. For instance, the exploration of a ship specifically designed for force projection in foreign littorals led to questioning the tendency to think that projecting global power requires massive Clausewitz type *attrition warfare* platforms. In other words, the SP2 results for this specific scenario called for a ship design balancing *attrition warfare* ASuW capabilities attributable to destroyers and frigates with the *manoeuvre warfare* tactical advantages of smaller fast-attack boarding vessels in order to incapacitate the enemy's will to fight. Attrition warfare advocates destroying an enemy's physical substance using the cumulative effect of superior firepower in a

decisive battle, whereas manoeuvre warfare advocates avoiding the enemy's conventional strengths and concentrating the right amount of force against its weaknesses.[85]

Moreover, when considering the examination of the capabilities resident in the Eilat Sa'ar 5 class multi-mission Israeli corvettes and Germany's newest K130 Braunschweig class ocean-going corvettes, the SP2 results indicated that projecting power globally could potentially be achieved with a fleet of well designed and affordable corvettes balancing modern combat capabilities with range. To that end, the conclusion of the SP2 evaluation of the Canadian status quo as a rank 3 medium global force projection navy suggested that any shortcomings in range and endurance could be remedied if a forward logistic support vessel accompanied the task group. Finally, as explicitely shown by the SP2 gap analysis between domestic and expeditionary ships, a corvette designed for expeditionary roles would also meet the continental requirements for sovereignty and hemismeric security, some in excess.

The SP2 process suggests that now is perhaps a good time to rethink the nomenclature used to classify the ships which constitute a modern fleet capable of tackling both asymmetric threats and the potential resurgence of state-on-state warfare. Meaningful taxonomy related to the ships primary function or payload such as AAD, littoral force projection and major conflict operations comes to mind. Note that the SP2 structure does not use the traditional definitions for types of ships (i.e. destroyer, frigate and corvette) which are historically based on size and displacement. Instead, the SP2 process speaks in terms of design parameters related to key user's requirements, ship's capability measure of performance and mission measure of effectiveness. If DND is to meet the level of ambition of the CFDS to the letter, on time and on budget, difficult strategic decisions will have to be made regarding the fleet composition, the

[85] Canadian Forces College, *Naval Doctrine Manual*, C-4.

inherent capabilities residing in its ships, and the maritime roles and responsibilities to be fulfilled. As suggested by Corbett, perhaps the expression in material of the strategic and tactical ideas that now prevail calls for a paradigm shift in naval doctrine and political posturing. The SP2 process can assist decision-makers assess which way to move forward, either with a uniform fleet of up to 15 reconfigurable surface combatants, which could be corvettes, or with a responsive navy composed of various building blocks that can be configured to the circumstances.[86]

In terms of forward strategic thinking, the unclassified, draft document produced by the Canadian Navy in 2010, *Horizon 2050: A Strategic Concept for Canada's Navy* draws attention to the possible re-emergence of state conflict in the Western Pacific region.[87] Consequentially, Canada is reminded once again of the requirement to maintain the capacity and capability to project credible, combat-capable maritime forces that can make a contribution to coalition or alliance maritime operations in order to control events in contested waters and contain or isolate conflict. To that end, the taxonomy used in *Leadmark 2020* to describe the naval roles and functions should perhaps be replaced by a more meaningful nomenclature reflecting the hierarchical functional decomposition of the CFDS roles and missions into the SP2 levels of abstractions, as illustrated in Figure 30. These levels of abstractions provide an effect-based approach to naval warfare which improves the understanding of the problem such that better solutions can be considered early in the conceptual design phase.

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[86] Hughes, *Implementing the Seapower Strategy*, 51.

[87] Elinor Sloan, "The Rise of China: Military Implications for Canada," *The Dispatch* IX, no. 1 (Spring 2011), 20, http://www.cdfai.org/newsletters/Dispatch%20-%20Spring%202011.pdf (accessed 21 April 2011).

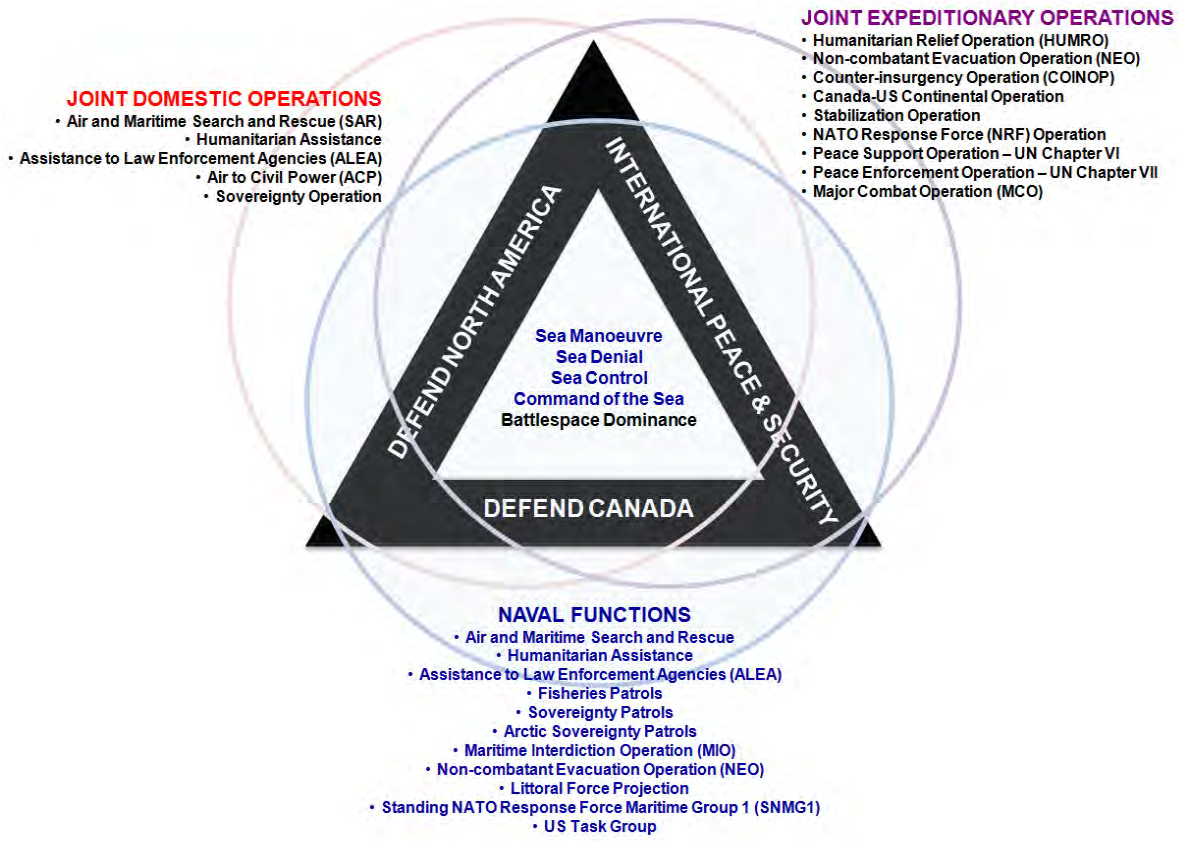

Figure 30 – SP2 Naval Function, CF Joint Activities and CFDS Core Roles

Internationally, the contribution that Canada can make to promote regional stability and deter acts of aggression is limited to what a 34 million strong nation can generate and sustain in terms of human capital, material resources and political will. As a member of both the UN and NATO, and the primary advocator for the responsibility to protect (R2P) framework, Canada has, as a matter of principle, the obligation to make a visible international contribution to peace and security. The R2P framework promoted an international consensus around the legitimate use of force to halt large-scale attacks on civilians through the International Commission on Intervention and State Sovereignty.[88]

[88] Foreign Affairs and International Trade Canada, "Responsibility to Protect," http://www.international.gc.ca/glynberry/protect-resp-proteger.aspx?lang=eng (accessed 21 April, 2011).

Domestically, with a coastline of 243,772 km and an area of responsibility over 11 million square kilometres (see Figure 31), Canada has a formidable challenge in setting priorities and allocating limited physical assets to maintain effective presence, security, surveillance and control coverage over its 200 nautical mile EEZ.[89] Given that most of the oceans catch and the sea lines of communications (SLOC) depend on the coastal waters within the EEZ, these zones are both the most productive and the most vulnerable. As Milan Vego (2008) explains, "naval power will continue to play a critical and perhaps vital role in protecting and preserving a nation's interests at sea, especially when prosperity and economic well-being depend on the free and uninterrupted use of the sea."[90] As a large coastal state with significant maritime interests, Canada's naval forces must maintain the independent ability to effectively conduct domestic operations to safeguard its sovereignty. This requirement is why the CF abides by the Canada First, not second or third, Defence Strategy.

The SP2 process is an important decision-making support tool to assist military leaders articulate in vivid and allegoric fashion the force planning and prioritization schemes to politicians. Rich from that knowledge, it is hoped that they may better understand the CF requirements and thus ably negotiate competing resources on its behalf.

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[89] Peter Avis, "Surveillance and Canadian Maritime Domestic Security," *Canadian Military Journal* 4, no. 1 (Spring 2003), 9-14, http://www.journal.forces.gc.ca/vo4/no1/policy-police-eng.asp (accessed 4 April 2011).

[90] Vego, *On Naval Power*, 17.

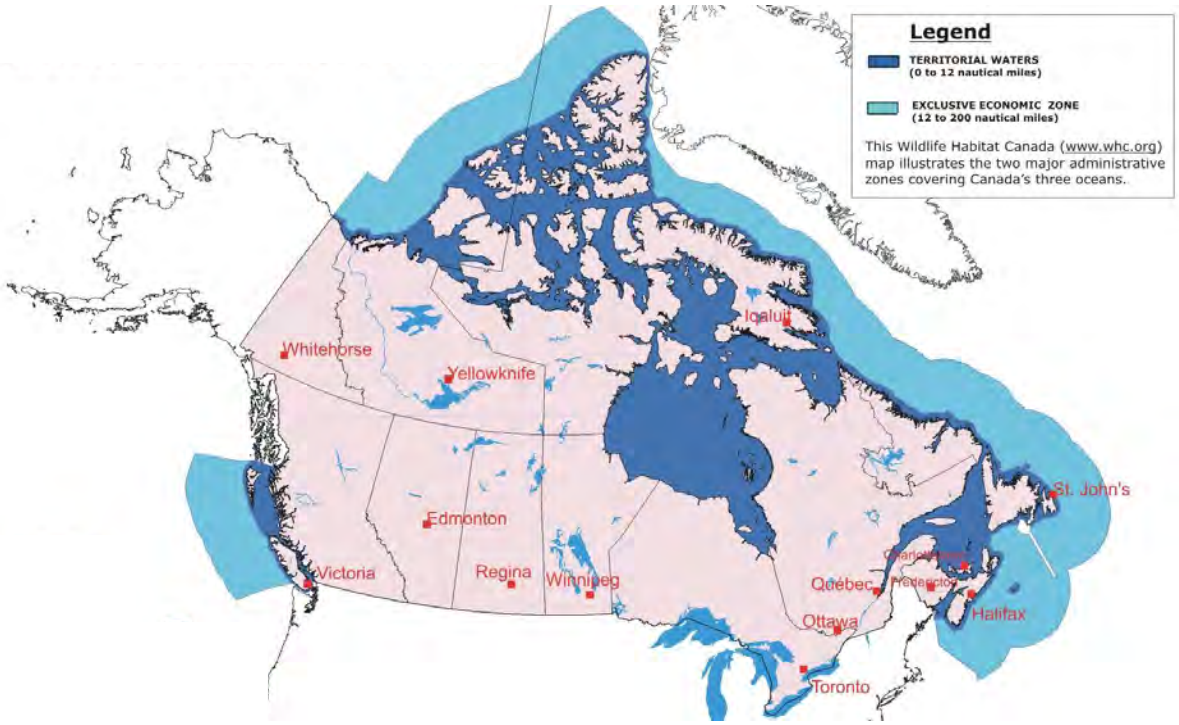

Figure 31 – Canadian Exclusive Economic Zone

Source: Wildlife Habitat Canada

CONCLUSION

Classical Greek philosophers Socrates and Plato explored the attributes of knowledge and inspired such considerations as knowing we know, knowing we don't know, not knowing we don't know, and ultimately the questioning of what do we really know with absolute certainty? These concepts transcended the ages and continue to afflict modern project management with strategic errors and biases such as underestimation, overestimation or worse "paralysis by analysis" or purposeful avoidance of decision making. Among the many tools a manager can use for strategic planning, the Strategic Planning and Prioritization (SP2) process stands out for its ability to readily capture concerns an dopinions, and explore the interdependencies and joint impacts of various uncertainties through "what if" scenarios so to increase shared knowledge and understanding of the critical variables.

The epistemic nature of the SP2 process allows the collective generation and evaluation of scenarios which challenges prevailing mid-sets and presumed correlations between uncertainties, while reducing subjective interpretations.[91] The purpose is not to eliminate all uncertainties and cover all options related to ship conceptual design but to circumscribe them so to instil a deeper appreciation of the critical factors. The visualization of these outcomes provides the catalyst for decision-makers to more confidently consider options they would otherwise ignore and move forward based on well-founded assumptions.

The SP2 process comprises several steps which were followed to the letter. The scope of planning envisaged a procurement process potentially taking 10 to 15 years within which period high volatility was assumed in terms of political, economical, societal, technological, legal, and industrial trends. For instance, external factors such market fluctuations, technological

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[91] Paul J. H. Schoemaker, "Scenario Planning: A Tool for Strategic Thinking," *MIT Sloan Management Review* 36, no. 2 (Winter 1995), 27, http://www.favaneves.org/arquivos/scenarioplanning.pdf (accessed 21 April 2011).

innovation rate, political election military agenda, and regional conflicts elsewhere in the world were assumed as influential elements. The organizational goals were clearly mandated by the CFDS core military roles and missions which were functionally decomposed and prioritized using a top-down approach into operational-level joint domestic and expeditionary CF activities, next into contributing naval functions, and finally into ship's capabilities corresponding to key user's requirements. The several levels of abstraction and the broad range of naval functions and joint CF activities inserted in the SP2 structure accounted for the plurality and unpredictability anticipated by the fog of war without computationally cluttering the model.

The results from the SP2 voting were synthesized into a portable decision-making support tool allowing users to interactively perform capability trade studies by adjusting the design parameters' measure of performance for a given scenario. The dynamic visualization of the cascading bottom-up effects on the naval functions, joint CF activities, strategic missions and geopolitical aspirations' measure of effectiveness stimulated collective strategic thinking whilst minimising individual biases. Using this shared framework, various scenarios were examined with each revealing different set of strategic options and requisite core capabilities. The culmination of the scenario exploration suggested that a paradigm shift in naval doctrine and political posturing may be inevitable as Canada may struggle to meet the explicit and implicit domestic and expeditionary CFDS requirements, on time and on budget. Perhaps a "good enough" solution would suffice.

Navy assets will undoubtedly continue to be useful tools for providing support to domestic and foreign policies because of their inherent flexibility, mobility, and political symbolism. Even in peacetime, the presence of a combat capable fleet-in-being carries a

significant diplomatic message of in terms of national interest, will, and intent.[92] Unconventional and asymmetric threats in the maritime domain have, however, drastically increased in diversity, intensity, sophistication and lethality since the Cold War era to include transnational terrorism, piracy and criminal networks involved in illicit trafficking in narcotics, humans, and weapons.[93] The combination of these threats in addition to the possible emergence of an Asian naval power makes it increasingly difficult to design a single large platform that can effectively respond to all possible missions within the spectrum of conflicts in open seas and in the littorals.

The design of such combat-capable, flexible and multi-role surface combatants is besieged by difficult challenges including: coping with unknown future global threats; using disparate technologies some not yet fully developed and others nearing obsolescence; attracting and retaining sailors not yet conceived; and building to cost over a long horizon in the face of unknown commodity, currency and labour fluctuations. The UTE-SP2 process may serve as a robust and adaptive departure point that will reduce the inherent risk, ambiguities and uncertainties laden to conceptual design activities. The SP2 process supports decision-makers in the process of challenging assumptions, evaluating cause-and-effect relationships, and assessing the accuracy, quality, stability, completeness, and relevance of the information and knowledge at hand, rather than merely assuming these characteristics.[94]

The purpose of the SP2 process is to develop a decision-making support and visualization tool connecting the technical staff, operators, senior managers, bureaucrats and politicians with a common language. It is a means to increase the collective understanding of the uncertainties

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[92] Canadian Forces College, *Naval Doctrine Manual*, C-5.

[93] Vego, *On Naval Power*, 8.

[94] Johansson and others, *Knowledge Maturity as a Means to Support Decision Making during Product-Service Systems Development Projects in the Aerospace Sector*, 37.

plaguing naval major crown projects by reconciling the design process paradox of making the most important and influential decisions early during the conceptual design phase while having the least knowledge and information. A complementary benefit of the SP2 process is that ingrained assumptions and rule-of-thumb based on gut feeling and intuition can be tested. This feature allows institutional leaders to more confidently make risky choices based on rational thinking rather than instinct. Making a more confident decision using the SP2 process does not mean that it is the right decision nor that all issues were attended to, it rather simply implies increased probability that the most important and contradictory aspects of the problem were collectively highlighted based on well-founded ideas and principles. Most and foremost, the SP2 framework is a living communication tool that should be used by all team members and that should continue to be adapted as the programme evolves and more information becomes available.

If all fails, the alternate solution is very simple. As always, the Navy can ask Treasury Board enough money to buy corvettes, motivate DND in designing frigates, and ask industry to build destroyers. When the incontestable inevitability that the budget exceeds its limit occurs, beg for forgiveness, and supplicate for more money in the name of national pride, sovereignty and regional economic stimulation. And get promoted while doing so. Having said that, Peter Haydon (2009) wisely suggested that ultimately, "the mix of ships in a navy must be established through trade-off between the types and numbers of ships that best provide the required operational capabilities and the total investment that a country is willing to make in its navy."[95]

[95] Peter Haydon, "Choosing the Right Fleet Mix: Lessons from the Canadian Patrol Frigate Selection Process," *Canadian Military Journal* 9, no. 1 (2009), 66, http://www.journal.forces.gc.ca/vo9/no1/doc/10-haydon-eng.pdf (accessed 15 March 2011).

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APPENDIX 1 –DESTROYERS AND FRIGATES BUILT IN CANADA SINCE 1945

Table 19 - Canadian Destroyers and Frigates Shipbuilding 1945-2010

Ship Name		Laid Down	Launched	Commissioned	Shipyard
DDH 205	ST. LAURENT	22-Nov-50	30-Nov-51	29-Oct-55	Canadian Vickers Ltd., Montreal QC
DDH 234	ASSINIBOINE	19-May-52	12-Feb-54	16-Aug-56	Marine Industries Ltd., Sorel QC
DDH 229	OTTAWA	08-Jun-51	29-Apr-53	10-Nov-56	Canadian Vickers Ltd., Montreal QC
DDH 206	SAGUENAY	04-Apr-51	30-Jul-53	15-Dec-56	Halifax Shipyard Ltd., Halifax NS
DDH 207	SKEENA	01-Jun-51	19-Aug-52	30-Mar-57	Burrard Dry Dock Ltd., North Vancouver, BC
DDH 233	FRASER	11-Dec-51	19-Feb-53	28-Jun-57	Burrard Dry Dock Ltd., North Vancouver, BC
DDH 230	MARGAREE	12-Sep-51	29-Mar-56	05-Oct-57	Halifax Shipyard Ltd., Halifax NS
DDE 257	RESTIGOUCHE	17-Jul-53	22-Nov-54	7-Jun-58	Canadian Vickers Ltd., Montreal QC
DDE 257	ST. CROIX	15-Oct-54	17-Nov-57	4-Oct-58	Marine Industries Ltd., Sorel QC
DDE 256	GATINEAU	30-Apr-53	3-Jun-57	17-Feb-59	Davie Shipbuilding Ltd., Lauzon QC
DDE 258	KOOTENAY	21-Aug-52	15-Jun-54	7-Mar-59	Burrard Dry Dock Ltd., North Vancouver, BC
DDE 259	TERRA NOVA	11-Jun-53	21-Jun-55	06-Jun-59	Victoria Machinery Depot Ltd., Victoria BC
DDE 260	COLUMBIA	11-Jun-52	01-Nov-56	07-Nov-59	Burrard Dry Dock Ltd., North Vancouver, BC
DDE 236	CHAUDIERE	30-Jul-53	13-Nov-57	14-Nov-59	Halifax Shipyard Ltd., Halifax NS
DDE 261	MACKENZIE	15-Dec-58	25-May-61	6-Oct-62	Canadian Vickers Ltd., Montreal QC
DDE 262	SASKACHEWAN	29-Oct-59	1-Feb-61	16-Feb-63	Victoria Machinery Depot Ltd., Victoria (and Yarrow) BC
DDE 263	YUKON	25-Oct-59	27-Jul-61	25-May-63	Burrard Dry Dock Ltd., North Vancouver, BC
DDE 264	QU'APPELLE	14-Jan-60	2-May-62	14-Sep-63	Davie Shipbuilding Ltd., Lauzon QC
DDH 266	NIPIGON	5-Aug-60	10-Dec-61	30-May-64	Marine Industries Ltd., Sorel QC
DDH 265	ANNAPOLIS	2-Sep-61	27-Apr-63	19-Dec-64	Halifax Shipyard Ltd., Halifax NS
DDG 280	IROQUOIS	15-Jan-69	28-Nov-70	29-Jul-72	Marine Industries Ltd., Sorel QC

Ship Name		Laid Down	Launched	Commissioned	Shipyard
DDG 283	ALGONQUIN	1-Sep-69	23-Apr-71	3-Nov-72	Davie Shipbuilding Ltd., Lauzon QC
DDG 282	ATHABASKAN	1-Jun-69	27-Nov-70	30-Nov-72	Davie Shipbuilding Ltd., Lauzon QC
DDG 281	HURON	1-Jun-69	9-Apr-71	16-Dec-72	Davie Shipbuilding Ltd., Lauzon QC
FFH 330	HALIFAX	19-Mar-87	30-Apr-88	29-Jun-92	Saint John Shipbuilding Ltd., Saint John, NB
FFH 333	TORONTO	22-Apr-89	18-Dec-90	29-Jul-93	Saint John Shipbuilding Ltd., Saint John, NB
FFH 331	VANCOUVER	19-May-88	8-Jul-89	23-Aug-93	Saint John Shipbuilding Ltd., Saint John, NB
FFH 334	REGINA	6-Oct-89	25-Jan-92	29-Dec-93	MIL-Davie Shipbuilding Ltd., Lauzon QC
FFH 332	VILLE DE QUEBEC	16-Dec-88	16-May-91	14-Jul-94	MIL-Davie Shipbuilding Ltd., Lauzon QC
FFH 336	MONTREAL	8-Feb-91	28-Feb-92	21-Jul-94	Saint John Shipbuilding Ltd., Saint John, NB
FFH 337	FREDERICTON	25-Apr-92	26-Jun-93	10-Sep-94	Saint John Shipbuilding Ltd., Saint John, NB
FFH 335	CALGARY	15-Jun-91	28-Aug-92	12-May-95	MIL-Davie Shipbuilding Ltd., Lauzon QC
FFH 339	CHARLOTTETOWN	18-Dec-93	1-Oct-94	9-Sep-95	Saint John Shipbuilding Ltd., Saint John, NB
FFH 338	WINNIPEG	20-Mar-93	25-Jun-94	23-Jun-96	Saint John Shipbuilding Ltd., Saint John, NB
FFH 340	ST. JOHN'S	24-Aug-94	26-Aug-95	26-Jun-96	Saint John Shipbuilding Ltd., Saint John, NB
FFH 341	OTTAWA	29-Apr-95	31-May-96	28-Sep-96	Saint John Shipbuilding Ltd., Saint John, NB

Source: Canadian Navy

APPENDIX 2 – MANAGEMENT PHASES FOR CAPITAL PROJECT APPROVAL

Table 20 - Management Phases for Capital Project Approval

Phase	Key Activities
Identification	• Production of a formal description of the capability deficiency linked to policy and performance expectations. • Identification of potential solutions in broad terms. • Preparation of a rough order of magnitude (ROM) cost estimate for planning purposes. • Preparation of an initial risk assessment. • Initiation of a Statement of Operational Requirement (SOR). • Preparation of a Project Charter. • Obtaining sponsoring Level One Management approval. • Synopsis Sheet (Identification) or SS(ID) to obtain: agreement on the identified capability deficiency; agreement with the proposed options to be examined; Vote 1 funding for the options analysis phase; and approval for the planning of the total anticipated capital project cost.
Option Analysis	• Approval of the Project Charter. • Conducting studies to produce a costed options analysis which examines the Capital requirements and the resulting Personnel, Operations and Maintenance (P, O&M) resource impact. • Conducting studies to produce an indicative total cost estimate of the preferred option. • Conducing studies to produce a substantive cost estimate of the definition phase or the first phase of a "gated" project. • Preparation of a Project Profile and Risk Assessment (PPRA) for projects greater than $5M or which are considered to be high risk. • Refinement of the SOR. • Establishment of the project Senior Review Board (SRB) and reviewing of project planning and documentation. • Synopsis Sheet (Preliminary Project Approval) or SS(PPA) to obtain: approval in principle (AIP); approval to proceed to the definition phase; Vote 5 funding for the definition phase for the preferred option, the anticipated total project cost estimate and the resulting P, O&M implications of implementing the project.
Definition	• Conducting studies to produce a final SOR. • Conducting studies to produce a substantive estimate of the total cost of the preferred option based on detailed system and component designs. • Conducting studies to produce an indicative estimate of the total project cost as well as substantive estimate of the cost of the phase of a "gated" project for which expenditure authority is being sought. • Conducting studies to produce a substantive estimate of the transition and recurring P, O&M costs associated with implementation of the project. • Preparation of a revised PPRA. • Creation of a Project Management Plan (PMP). • Convening of the project SRB to review documentation and provide advice, where required. • Synopsis Sheet (Effective Project Approval) or SS(EPA) to obtain: approval for the selected option; agreement with the P, O&M costs and method for funding associated with the implementation of the selected option; agreement to proceed to the implementation phase with substantive cost estimates; and Vote 5 funding for the implementation phase.

Phase	Key Activities
Implementation	• Final shifting of project leadership from sponsoring organization to the implementing organization. • Execution of the PMP and transition to the Life Cycle Management System (LCMS). • Project reporting as required. • Annual or as required monitoring by the project SRB. • Attain Full Operational Capability (FOC) indicating that project implementation has satisfactorily met specified performance documented in the SOR. • Preparation of the Project Completion Report (PCR) and Lessons Learned.
Close Out	• Completing the Project Close-out Checklist (PCOC). • Closing down the project office. • Releasing unneeded funds for reallocation. • Writing the PCR.

Source: Department of National Defence. *Project Approval Guide*. 2009.

APPENDIX 3 – 2005 DEFENCE POLICY STATEMENT – MARITIME TASKS

Protecting Canada and Canadians

The Maritime Forces (Regular and Reserve) will:

- place much greater emphasis on protecting Canada;
- implement specific National Security Policy commitments by:
    - leading the coordination of the on water response to a maritime threat or a developing crisis in our Exclusive Economic Zone and along our coasts,
    - helping develop a common maritime picture, including by expanding the number of High Frequency Surface Wave Radars on each coast,
    - leading the development of fully integrated interagency Marine Security Operations Centres,
    - cooperating closely with other government fleets and agencies involved in the surveillance of our ocean areas,
    - exploring cooperation with other government agencies in monitoring our internal waters, such as the St. Lawrence Seaway and the Great Lakes, and
    - strengthening their links with Canadian stakeholders and the appropriate U.S. departments and agencies to facilitate better maritime security cooperation;
- increase their support to other government departments in protecting endangered fish stocks, monitoring illegal drug and immigration activity, conducting environmental surveillance, and carrying out search and rescue operations;
- provide, when required, submarines in direct support of the Special Operations Group for operations within Canada's ocean regions;
- provide a naval task group of up to four combatant vessels on each coast, with embarked maritime helicopters and a national command component, to protect the sovereignty and security of our oceans and maritime areas of jurisdiction:
    - one task group designated for operations as the maritime contribution to the Standing Contingency Task Force, and
    - the other available to deploy as part of a Mission-Specific Task Force;
- enhance their surveillance of and presence in Canadian areas of maritime jurisdiction, including the near-ice and ice-free waters of the Arctic; and
- sustain indefinitely, on each coast, a ready-duty ship, capable of responding to national contingency or search and rescue operations in our waters and maritime approaches.

CANUS Defence Relationship

Canada will examine with the United States a number of security and defence areas in which our two countries could work more closely together, including:

- preventing or mitigating the impact of potential maritime attacks by:
    - increasing bi-national maritime surveillance activities, and
    - enhancing the sharing of maritime intelligence, information and assessments to better advise and warn both governments;
- improving our ability to respond to maritime crises, on a case-by-case basis, with the formal approval of both governments;

- developing military-to-military arrangements for the support of civilian authorities during crises and emergencies; and
- ensuring that maritime forces, both regular and reserve, cooperate even more closely with the U.S. Navy and Coast Guard;

Contributing to a Safer and more Secure World

The Maritime Forces will be able to:

- sustain indefinitely the deployment overseas of two ships (one from each coast) with embarked maritime helicopters, or a submarine and a ship, for operations in direct support of the Special Operations Group or as forward elements of the Standing Contingency Task Force anywhere in the world;
- sustain for up to six months a task group of up to four combatant vessels with the capability for a national or multinational command component for operations abroad. This task group will be capable of precision fire and support to forces ashore and will be used as an integral element of the Standing Contingency Task Force or in support of other national objectives; and
- deploy a second task group for up to six months, either as a follow-on force to the Standing Contingency Task Force or as part of a separate Mission-Specific Task Force.

Source: Department of National Defence. *Canada's International Policy Statement. A Role of Pride and Influence in the World: Defence*. 2005.

APPENDIX 4 – SHIP CAPABILITY LEVELS

Table 21 – Ship Capability Levels

Level	Capability
Anti-Air Warfare (AAW)	
0	No AAW capability
1	Limited surveillance and reconnaissance, and self-defensive AAW capabilities
2	Self-defensive capabilities against over-the-horizon air threats
3	Offensive capabilities against over-the-horizon air threats
4	Anti-ship ballistic missile defence capability
5	Theatre ballistic missile defence capability
Anti-Surface Warfare (ASuW)	
0	No ASuW capability
1	Limited surveillance and reconnaissance, and short-range (up to 3,000 yds) self-defence ASuW capability (e.g., 40mm Guns)
2	Medium range (up to 8,000 yds) self-defence ASuW capability (e.g., 3" Gun)
3	Extended range (up to 12,000 yds) self-defence ASuW capability (e.g., 5" Gun)
4	Offensive to the horizon ASuW capability (e.g., SSM)
5	Offensive over-the-horizon ASuW capability (e.g., helicopter with SSM)
Anti-Submarine Warfare (ASW)	
0	No ASW capability
1	Limited self-defensive capabilities against submarine threats inside the Torpedo Danger Zone
2	Limited self-defensive capabilities against submarine threats outside the Torpedo Danger Zone
3	Extended ASW capability (e.g., ASW capable helicopter)
4	Area Offensive ASW capability (e.g., long range sensors, weapons and ASW capable helicopter)
5	Theatre-wide anti-submarine warfare capabilities (e.g., multi-static sonar and CEC)
Mine Warfare (MW)	
0	No mine warfare capability
1	Limited mine detection (i.e., limitted surveillance and reconnaissance sensors for high area search rate with low false alarm generation)
2	Mine detection (i.e., rapid and wide area detection, classification and identification)
3	Mine avoidance (i.e., mines location marked and communicated (C4I) for safe passage and SLOC)
4	Mine clearing (i.e., neutralise, breach and destroy)
Boarding	
0	No capability to board other vessels
1	Conduct day time non-opposed boarding in calm seas (i.e., SS < 3)
2	Conduct day time opposed boarding in calm seas (i.e., SS < 3)
3	Conduct day time opposed boarding in rough seas (i.e., SS ≥ 3)
4	Conduct night time opposed boarding in rough seas (i.e., SS ≥ 3)
Naval Fires Support	

Level	Capability
0	No capability to conduct naval fires
1	Conduct volume fires
2	Conduct precision fires
3	Conduct coordinated fires
C2, Comms, Computers and Intelligence (C4I)	
0	No C4I capability
1	Automatic weapons control and ability to synthesize external target data (i.e., CMS and Datalink)
2	Additional ability to have limited global communications (i.e., Narrowband SATCOM)
3	Additional ability to have high bandwidth communications (i.e., Wideband SATCOM)
4	Ability to conduct cooperative engagements with other friendly assets
Organic Air	
0	No organic air capability
1	Capability to land organic air assets onboard (i.e., flight deck)
2	Capability to land and house a organic air assets onboard (i.e., flight deck and hangar)
3	Capability to maintain and support air assets onboard (e.g., embarked helicopter)
4	Capability to maintain and support multiple air assets onboard (e.g., CH-148 + Firescout)
Seabasing and Sealift	
0	No capability to carry additional cargo or transfer cargo on board
1	Carry 2 x 20-foot-long (6.1 m) ISO containers (TEUs)
2	Carry 4 x 20-foot-long (6.1 m) ISO containers (TEUs)
3	Carry and load/offload 4 x 20-foot-long (6.1 m) ISO containers (TEUs)
4	Carry and load/offload 4 x 20-foot-long (6.1 m) ISO containers (TEUs) in unimproved piers
Maximum Sustained Speed	
0	Maximum sustained speed of less than 15 kts
1	15 kts $\leq$ Maximum sustained speed < 20 kts
2	20 kts $\leq$ Maximum sustained speed < 25 kts
3	25 kts $\leq$ Maximum sustained speed < 27 kts
4	27 kts $\leq$ Maximum sustained speed < 30 kts
5	30 kts $\leq$ Maximum sustained speed < 35 kts
6	Maximum sustained speed $\geq$ 35 kts
Range	
0	Ship has a maximum range at cruise speed of less than 1,000 nmi
1	Ship has a maximum range at cruise speed between 1,000 nmi and 3,000 nmi
2	Ship has a maximum range at cruise speed between 3,000 nmi and 5,000 nmi
3	Ship has a maximum range at cruise speed between 5,000 nmi and 7,500 nmi
4	Ship has a maximum range at cruise speed between 7,500 nmi and 10,000 nmi
5	Ship has a maximum range at cruise speed of more than 10,000 nmi
Unsupported Endurance	
0	Ship can only deploy without logistical support for up to 10 days

Level	Capability
1	Ship can only deploy without logistical support for up to 20 days
2	Ship can only deploy without logistical support for up to 30 days
3	Ship can only deploy without logistical support for up to 60 days
4	Ship can only deploy without logistical support for up to 90 days
5	Ship can only deploy without logistical support for more than 90 days
Transit in Polar Ice (PC) Conditions	
0	No ice transit capability
1	PC 7: Summer/autumn operation in thin first-year ice which may include old ice inclusions
2	PC 6: Summer/autumn operation in medium first-year ice which may include old ice inclusions
3	PC 5: Year-round operation in medium first-year ice which may include old ice inclusions
4	PC 4: Year-round operation in thick first-year ice which may include old ice inclusions
5	PC 3: Year-round operation in second-year ice which may include multiyear ice inclusions
6	PC 2: Year-round operation in moderate multi-year ice conditions
7	PC 1: Year-round operation in all Polar waters
Survivability	
0	Ship designed to SOLAS Standards
1	Ship designed to Commercial Class Rules (e.g., LRS, GL, ABS, etc.)
2	Ship designed to Partial Naval Rules (e.g., redundant machinery rooms and watertight bulkheads)
3	Ship designed to Naval Rules
4	Ship designed to Naval Ship Code

APPENDIX 5 – DEFENCE POLICY STATEMENTS 1964 - 2008

Table 22 – Defence Policy Statements from 1964 to 2008

Year	Paper	Defence Policy Priorities
1964	White Paper on Defence	The objectives of the Canadian defence policy, which cannot be dissociated with foreign policy, are to: • Preserve the peace by supporting collective defence measures [with UN, NATO and US] to deter military aggression; • Support Canadian foreign policy including that arising out of our participation in international organizations; and • Provide for the protection and surveillance of our territory, our air-space and our coastal waters.
1971	Defence in the 70s: White Paper on Defence	The policy announced by the Prime Minister on April 3, 1969, initiated the process of adjusting the balance between Canadian defence activities to ensure that priorities for defence were responsive to national interest and international developments. Four major areas of activity for the CF were identified in summary form as follows: • The surveillance of our own territory and coast lines, i.e. the protection of our sovereignty; • The protection of North America in co-operation with the US forces; • The fulfilment of such NATO commitment as may be agreed upon; ad • The performance of international peacekeeping roles as we may from time to time assume.
1987	Challenge and Commitment: A Defence Policy for Canada	Canadian defence policy will continue to be based on a strategy of collective security within the framework of the North Atlantic Alliance, including the continental defence partnership with the US. Within this broad framework, defence policy will continue to: • Maintenance of strategic deterrence, • Credible conventional defence, • Protection of Canadian sovereignty, • Peaceful settlement of international disputes, and • Effective arms control.
1988 - 1989	Defence Update	
1992	Canada Defence Policy	The defence of Canada's sovereignty, our continued participation in collective security arrangements, and our aspiration to help resolve regional conflict, all call for the maintenance of flexible, capable armed forces. These forces will have to adapt to new domestic realities and new geostrategic conditions on the basis of the following priorities: • Defence, sovereignty and civil responsibilities in Canada; • Collective defence arrangement through NATO, including our continental defence partnership with the US; • International peace and security through stability and peacekeeping operations, arms control verification, and humanitarian assistance.

Year	Paper	Defence Policy Priorities
1994	White Paper on Defence	The White Paper concludes that to maximize the contributions of our armed forces, their traditional roles: • protecting Canada, • cooperating with the United States in the defence of North America, and • participating in peacekeeping and other multilateral operations elsewhere in the world, should evolve in a way that is consistent with today's strategic and fiscal realities. Given that the direct military threat to the continent is greatly diminished at present, Canada will reduce the level of resources devoted to traditional missions in North America. It will, however, remain actively engaged in the United Nations, NATO, and the Conference on Security and Cooperation in Europe.
2005	Defence Policy Statement	The tragedy of September 11, 2001 proved to Canadians that we are vulnerable to the threat of terrorism and the spillover effects from failed and failing states. This policy, therefore, establishes [three priorities]: • Protect Canada and Canadians. The defence of Canada as our first priority. • Canada US defence relationship. The effective defence of Canada and North America has always required working collaboratively with the United States. We will build on the successful bilateral defence arrangements currently in place, such as NORAD. • Contributing to a safer and more secure world. Our new defence policy will give the Canadian Forces the guidance they need to help Canada convey its distinct values and particular approach to conflict resolution around the world.
2008	Canada First Defence Strategy	• Defending Canada: *Delivering Excellence At Home* • Defending North America *A Strong and Reliable Partner* • Contributing to International Peace and Security *Projecting Leadership Abroad*

Source: Canada. Department of National Defence. Defence Policy Archives. www.forces.gc.ca/admpol/defence%20policy%20archives.html

APPENDIX 6 – LITTERATURE SURVEY OF WORLD WIDE SURFACE SHIPS

Table 23 – Literature Survey of World Wide Surface Ships

Ship Class Name	Country	Type	Pers	IOC (yr)	LOA (m)	Beam (m)	Draft (m)	Δ (tonne)	Range (nm)	Speed (kn)
Andrea Doria (Horizon)	Italy	DD	200	2008	152.9	20.3	8.00	6635	7000	29.0
Arleigh Burke (Flight IIA)	US	DD	276	2000	155.3	20.3	6.70	9155	4300	31.0
Daring (Type 45)	UK	DD	232	2009	152.4	21.2	5.30	7450	7000	31.0
Forbin (Horizon)	France	DD	197	2008	153.0	20.3	5.80	7050	7000	29.0
Hobart (AWD) (F100)	Australia	DD	234	2014	146.7	18.6	4.90	6250	5000	28.0
KDX-2	South Korea	DD	200	2003	154.4	16.9	4.30	5500	4000	29.0
Acquitaine (FREMM)	France	FF	145	2012	137.0	19.0	5.00	6000	6000	27.5
Alvaro de Bazan (F100)	Spain	FF	200	2002	146.7	18.6	7.20	5853	4500	28.0
Bergamini (FREMM)	Italy	FF	165	2012	142.2	19.7	5.40	5950	6000	27.0
Bergamini (FREMM)	Italy	FF	165	2012	142.2	19.7	5.40	5950	6000	27.0
De Zeven Provincien (LCF/F124)	Netherlands	FF	204	2002	144.2	18.8	5.20	6048	5000	28.0
Formidable	Singapore	FF	?	2007	114.0	16.0	5.00	3200	4000	27.0
Ivar Huitfeldt (Absalon Derivative)	Denmark	FF	165	2011	138.7	19.8	6.30	5850	9000	28.0
Nansen (F-85)(evolved F100)	Norway	FF	146	2006	133.3	16.8	4.90	5290	4500	26.0
Saschen (F124/LCF)	Germany	FF	255	2004	143.0	17.4	6.90	5600	4500	30.0
Thetis	Denmark	FF	72	?	112.5	14.4	6.0	3500	8500	20.0
Type 125	Germany	FF	190	2014	143.0	18.4	5.00	6800	4000	26.0
Barroso	Brazil	CVT	145	2002	103.4	11.4	4.0	2350	4000	29.0
Baynunah	UAE	CVT	44	?	70.0	11.0	2.8	844	2400	32.0
Braunschweig K130	Germany	CVT	66	2008	88.8	13.2	4.8	1840	4000	26.0
Braunschweig K130	Germany	CVT	50	2008	89.1	13.3	3.4	1840	4000	26.0
Brunei	Brunei	CVT	79	?	95.0	12.8	3.6	1940	5000	30.0
BVL	Venezuela	CVT	64	2009	80.0	11.5	3.7	1500	4000	22.0
Commandante	Italy	CVT	70	2001	88.4	12.2	4.6	1520	3500	26.0
Eilat (Sa'ar 5 class)	Israel	CVT	74	1994	86.0	11.9	3.2	1227	3500	33.0
Eilat (Sa'ar 5 class)	Israel	CVT	74	?	86.0	11.9	3.2	1227	3500	33.0
Gowind 200	Bulgaria & France	CVT	85	**?**	105.0	14.2	**??**	2500	2970	27.0
Kedah	Malaysia	CVT	83	?	91.1	12.0	3.0	1650	6050	22.0
Kilic	Turkey	CVT	45	?	62.4	8.5	2.5	552	1050	38.0
Lekiu	Malaysia	CVT	146	?	106.0	12.8	3.0	2270	5000	27.0
MEKO A-100	Malaysia & Poland	CVT	68	2006	91.1	13.4	4.4	1650	6050	22.0
Meko A200	South Africa	CVT	124	2006	121.0	16.3	6.0	3700	8000	27.0
MILGEM	Turkey	CVT	93	2011	99.0	14.4	3.8	2000	3500	29.0
Orkan (Sassnitz)	Poland	CVT	36	?	49.8	8.7	2.2	326	1600	38.0
SIGMA	Indonesia	CVT	80	?	90.7	13.0	3.6	1692	4000	28.0
Visby	Sweden	CVT	43	?	73.0	10.4	2.4	620	3000	35.0
Cyclone	US	OPV	48	1993	51.9	7.9	2.4	354	2500	35.0
Flyvefifken SF300	Denmark	OPV	29	?	54.0	9.0	2.5	450	2400	30.0
Machitis	Greece	OPV	49	?	56.5	10.0	2.7	575	2000	24.0
PKX	South Korea	OPV	40	?	63.0	9.0	5.0	570	2000	40.0
Stan Patrol 4100	Netherlands	OPV	12	1998	42.8	6.8	2.5	205	2000	26.0

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