An Engineer's Outline of Canadian Naval History, Part III (1970-2014)

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L'histoire de l'ingénierie de la Marine canadienne dans l'ère après-RCN (« COMAR ») se caractérise principalement comme l'ère de la frégate de la classe Halifax. Grâce à la conception, l'intégration et la construction, le développement ultérieur et le déploiement, la frégate canadienne de patrouille a symbolisé la croissance et la maturation techniques de la marine canadienne, évoluant de la poursuite d'une voie indépendante de développement pour répondre aux exigences opérationnelles du service national, jusqu'à la coopération, l'interdépendance et l'interopérabilité face aux défis multi-nationales communes. A cette même époque, la marine a également démontré cette évolution à travers un certain nombre d'autres développements en matière de capacité, tels le remplacement des sous-marins, le lancement de programmes de remplacement des navires de réapprovisionnement, une capacité de présence dans l'Arctique, et un remplacement pour destroyers et frégates. Les leçons longues et dures apprises au cours de chacun de ces projets ont positionné la marine pour réussir matériellement en entrant dans son deuxième siècle. La fin du document comprend un sommaire de perspectives sur un siècle de l'ingénierie navale canadienne.

In *The RCN in Retrospect*, the proceedings of the first of these Canadian naval historical conferences, Captain Jim Knox authored a 2-part paper entitled "An Engineer's Outline of RCN History" covering the period 1910-68.[1] This reviewed the technical history and experience of the RCN from 1910 up to integration and unification in the late-1960s, culminating in the transition of the Royal Canadian Navy into Maritime Command (MARCOM). As such, 'the RCN story' concluded with the pending delivery of the two Protecteur-class purpose-built operational support ships (OSS), the evolution of the General Purpose Frigate into the DDH-280 Iroquoi*s*-class destroyer, the acquisition of the three Oberon-class conventional submarines, and the development and eventual lay-up of the hydrofoil HMCS *Bras d'Or*. Captain Knox's conclusion was that it was the

1 J.H.W. Knox, "An Engineer's Outline of RCN History, Part I" and "Part II," in James Boutilier (ed.), *The RCN in Retrospect, 1910-1968* (Vancouver: UBC Press, 1982), 96-115 and 317-333.

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story of "a continuing process: the evolution of naval engineering."

This paper aims to extend this story up to the present, filling in the list of ships and systems acquired, the trials and tribulations of the process, and the necessarily heroic efforts of the engineering branch to overcome the twin challenges of bureaucratic processes and the uneasy match of high performance technology with an unforgiving environment. This initially was conceived of as an essentially chronological tale, for, with all its limitations as an organizing principle for the paper, the forward march of time is one of the few sure things in this business. However, Knox's characterization of the naval engineering story as a continuing and evolutionary process is a suggestive one. Evolution is an untidy business, and the technical evolution of a navy is similarly untidy, subject to many currents and counter-currents in the decision-making environment, not all of which are subject to either control or accurate forecast. As just one example, at the time of the conference at which this paper was delivered, no one present could have predicted the restoration of the 'Royal' prefix to the name of the Canadian Navy, but that is precisely what the government directed a slightly more than a year later, suggesting the framing of this chronology (with only slight adjustment for updates to the time of publication) as 'the MARCOM era'.

In the final analysis, from a naval operator point of view, there is a certain 'survival of the fittest' aspect. To quote Captain Corky Graham USN, design manager of the DDG-51 project, "the best ship is the one that gets built."[2] In the period of Canadian naval history in question, the most significant 'ship that got built', the platform that dominates the era, is the Halifax-class frigate, the outcome of the Canadian Patrol Frigate or CPF Project. This can rightly and deservedly be viewed as the defining capability of the era, even to the point of characterizing the post-RCN/MARCOM era as 'The CPF Era', notwithstanding that class now is emerging from what is viewed as its mid-life modernization refit. This then suggests a trio of inter-twined themes of continuity, change, and sustainment, all woven around the story of this single platform.

In keeping with the conference theme, it is also possible to view this period through the prism of shared and contrasted Commonwealth and allied experiences in dealing with the same challenges. The Canadian view of this long-cycle comparison would suggest a three-step progression, from dependence to independence to inter-dependence: initial dependence on the Royal Navy 'mother-ship' for engineering guidance, standards and traditions; evolution to independence in terms of distinct national choices with respect to evolution of naval materiel; and finally achievement of inter-dependence/interoperability/collaboration in terms of Commonwealth and allied development of a more sophisticated view of flexible solutions to common problems and challenges.

Due to the limitations of space, a number of themes important to some readers

2 This was a phrase used by Capt Graham in a one-week course he taught (and attended by the author in the mid-1980s) entitled Ship Design (emphasis Big 'S' Big 'D'), to distinguish the *real-politik* aspect of ship acquisition project management from the ship-science aspect of naval architecture.

will be glossed over in what follows, but are covered in some further detail in a longer version of this paper to be placed on deposit at the DND Directorate of History and Heritage (DHH).

Continuity: Maintaining the Fleet in Being

Taking the first thread, naval engineering at the beginning of the 1970's was concerned in large measure with the objective of continuity:

- the maintenance of the fleet in being at the end of the RCN era;
- the culmination of force development and acquisition activities begun during the RCN era; and
- the evolution of those assets going forward.

It was, to a significant extent, a period of consolidation of naval capability.

On proclamation of the Canadian Forces Reorganization Act, 1 February 1968, the Canadian navy (or more exactly, the Sea Element of the Canadian Armed Forces) inherited from the RCN what seemed a bright and promising future in materiel terms. The twenty ships based on the common platform of the St. Laurent hullform and Y100 propulsion plant were all under 15 years old, seven completing conversion to DDH (helicopter-carrying destroyer) configuration and four being upgraded with ASROC (a rocket-thrown anti-submarine torpedo system). The three Canadian Oberon-class submarines *Ojibwa*, *Onondaga* and *Okanagan* had been recently commissioned, and the capabilities of the replenishment ship *Provider* were about to be augmented with the Operational Support Ships (soon to be re-styled as AORs or Auxiliary Oiler Replenishment) *Protecteur* and *Preserver.*

The naval engineering branch and organization at the time of integration were essentially little changed from the immediate post-war orientation. The specialty of combat systems engineering was new and there were a small number of naval architects in uniform, but on board ship and ashore the term 'engineering' was taken uniformly to refer to the domain of marine systems engineering, focusing on propulsion, power generation and distribution, and auxiliaries.

However, the naval engineering headquarters and coastal structures were entering into a state of flux. Prior to integration, the materiel support functions were largely decentralized to the three services as an integral element of operational functions. In Ottawa, the naval materiel support structure of the 1950s and 1960s had consisted of a Chief of Naval Technical Services (CNTS), a rear-admiral (with subordinate commodores as Deputy CNTS, Engineer-in-Chief, Naval Constructor-in-Chief, Electrical Engineer-in-Chief, Director-General of Naval Ordnance, and Supply Officer-in-Chief, and captains as Assistant CNTS Ships and Air).[3]

Following integration, there was a shift over time, from direct support of combat operations to increasing the efficiency of materiel support under peacetime conditions, with a gradual loss of much of the doctrine and systems infrastructure needed for wartime

3 *The Navy List*, January 1960.

support operations.[4] The separate services materiel support organizations had given way initially to an integrated CF materiel support structure which featured a single force Chief of Technical Services with a Deputy Chief of Engineering (DC Eng) and a Commander Material Command (MATCOM) reporting to him. The naval materiel support functions were split between a Director General Maritime Systems (DGMS) under DC Eng, and a Director of Maritime Maintenance (DMM) under MATCOM.

In 1972, Canadian Forces Headquarters (CFHQ) was disbanded and the materiel functions were split and recombined in a new NDHQ (National Defence Headquarters) structure, with Chiefs of Engineering and Maintenance and of Supply (CEM and CS respectively) reporting to an Assistant Deputy Minister (Material) (ADM Mat). The naval engineering function was vested in a new Director General Maritime Engineering and Maintenance (DGMEM) at the commodore rank, with naval captains as Directors of Maritime Equipment Engineering (DMEE), Maritime Combat Systems (DMCS), and Maritime Engineering and Maintenance (DMEM). There was also a Directorate of Maritime Facilities and Resources (DMFR) and, for a brief period (a few years), a Directorate of Maritime Program Management (DMPM). Later, a Director Maritime Engineering Support (DMES) (a civilian captain-equivalent position) was added to cover specialist engineering functions such as survivability, habitability, and materials, as well as maintenance policy and information systems. The naval supply and procurement function was vested in a Directorate of Procurement and Supply Maritime (DPSupM) and a Director of Procurement and Supply for Communications and Electronics (DPSCE) reporting to CS.

In Maritime Command (MARCOM) in Halifax there was a Chief of Staff Material (COS MAT) at the commodore level.[5] At the waterfront level on each coast, there was initially (1968-73) a commodore in charge of the Dockyard, later becoming the base commander at the rank of naval captain. The Dockyard command structure evolved into three separate units: a Ship Repair Unit (SRUA [Atlantic] and SRUP [Pacific], both under naval captains), a Naval Engineering Unit (NEUA and NEUP, under a captain and a commander respectively) and a Fleet Maintenance Group (FMGA and FMGP, under a commander and a lieutenant-commander respectively). Interestingly in light of subsequent recombination, the NEUs were relatively new units in the mid-1970s, the engineering function having previously been part of the SRUs.

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4 LCdr T. Wyand, "The evolution of the Naval Engineering and Maintenance Organization from 1968 until the Present" (unpublished staff paper, 2009 [copy in possession of author]).

5 This diarchy has led to a considerable amount of tension between the coastal operational and central headquarters engineering and support functions ever since integration, reflecting differences in outlook (or immediate imperative) with respect to authority over such issues as configuration management, maintenance philosophy, and the like, and who should pay. This tension was only partially resolved with the reduction to one naval engineering commodore (as DGMEPM under ADM(Mat)) and his recognition also as the Chief of Maritime Staff's 'Chief Naval Engineer'. Ironically, this led to a different type of tension, as one ADM(Mat) voiced the concern "that he was not sure all his 'EPMs' had both feet in the 'Mat' camp" – in effect, and by design, this was perfectly true.

While there were the perennial challenges of applying limited resources (manpower, time and cash) to the technical issues of supporting operations, and the occasional naval engineering catastrophe to remind navies of the risks of the profession,[6] by and large the Canadian navy in the late-1960s and early-1970s was reasonably pleased with itself in material and organizational terms. The challenges (the sea first, then the USSR) were well understood; technology was on the march, but had not yet resulted in the data integration and proliferation explosion which would revolutionize warfare and the associated warfare systems production; and assumptions about the career motivations, interests, aspirations and plain availability of the next generations of replacement engineers and technicians had not yet been cast into doubt.

Already, however, there were some clouds on the horizon. The metaphorical early warnings of this were represented by two events: the paying off on 3 July 1970 of the aircraft carrier HMCS *Bonaventure* soon after completing an expensive ($18M) refit, and the cancellation on 2 November 1971 of the hydrofoil program soon after HMCS *Bras d'Or*'s successful sea trials.

These omens were overshadowed by the crowning glory of this period: the introduction in the early-1970s of the Iroquois-class destroyers, the much heralded 'Sisters of the Space Age' as they were portrayed in a 1974 National Film Board of Canada documentary. These represented a significant watershed in Canadian naval procurement. Not only did they introduce some significant technical innovations (the first Western naval vessel committed to all gas-turbine propulsion, the first use of a single 'raft' for the entire propulsion plant; the highest-powered controllable-pitch propellers at the time; the integrated combat system achieved through the CCS-280 central command and control system[7]), but the program also was notable for both the confused gestation in force development terms and the departure from the previous norm for design and contracting. Previously, the navy had prepared all the working drawings internally up to the point of what was known as the 'contract design' stage and then contracted for build. The Iroquois class was a shift to a fixed price approach in which the overall responsibility was transferred to the shipyards, while the navy had separate contracts to supply large elements of the ship, such as the whole propulsion system and the combat system, as 'government supplied material' (GSM).

This change of process caused a number of problems due to the unfamiliarity of the approach and hence missing links – for example, the GSM contracts did not include requirements for contractors to supply the information that the Naval Central Drawing Office (NCDO) would need to integrate the systems into the ship design, with the result that much effort and schedule was lost in draughtsmen having to go into warehouses to actually pick measurements off equipment. Another example was that the shipbuilders had quoted narrowly based on the preliminary design drawings, which were necessarily

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6 For example, the 1969 HMCS *Kootenay* gearbox explosion in the RCN and the US Ships *Forrestal* (1967) and *Belknap* (1975) fires in the USN.

7 Cmdre D.R. Boyle, "Naval Engineering Accomplishments in Canada," paper presented to the Engineering Institute of Canada Centennial Convention in Montreal, 21 May 1987, 14-15. At the time, Boyle was DGMEM.

incomplete at that stage of design in terms of many details (such as air conditioning ducting, dampers, etc) and then claimed the effort to fill in the gaps as costed design changes. Thus, although the contract was written for the lead yard as a prime contractor with the overall responsibility of being in charge and putting it all together, the actual construct of the project both confused the lines of responsibility and was lacking some elements. Commodore Bill Broughton, who as a commander had been the Project Systems Engineer, later observed that "the greatest risk in putting a ship together is managing the technical information to do it. It's not selecting the gas turbine, it's not designing the hull, it's the technical detail in order to fit all the stuff in the ship so it will work."[8]

Notwithstanding the delivery of this new generation of technology and naval capability, however, by the late-1970s and the early-1980s the navy and the naval engineering establishment were faced with a mounting struggle to deal with the joint challenges of maintaining an aging and increasingly operationally irrelevant fleet, while simultaneously trying to tool up and reorient in intellectual, philosophical and resource terms for the needed fleet replacement programmes.

By the late-1970s, the 'steamers' (the St. Laurent and derivative classes) were all at mid-life and showing the effects of their age. With replacement programs being delayed, DGMEM undertook a Destroyer Life Extension Cost Analysis (DECLA) to assess the costs of bridging a threatened capability gap. The consequential destroyer life extension (DELEX) project was proposed in February 1979, recognizing that the design life expectancy of the steamers would be reached between 1980 and 1989. This project proposed to extend the useful lives of sixteen of the nineteen ships. This investment was not a moment too soon. In a coincidental demonstration of the effects of age, the discovery in the fall of 1981 of stress-corrosion cracking in super-heater headers caused all nineteen ships to be ordered alongside for inspection, and the subsequent 'Boiler Get-Well' programme ultimately required the replacement of the super-heater headers in eight ships. The DELEX program had limited effect on operational capability. Although the CANEWS (Canadian Electronic Warfare System) installation gave the DELEX steamers an EW capability which exceeded that initially installed in the newer DDH-280s, overall the post-DELEX ships were assessed in a Maritime Warfare Bulletin of 1985 as having capabilities of only 36 percent and 12 percent respectively in anti-air and surface warfare terms, and posing a potential liability to multinational forces with which they might operate.[9] Notwithstanding these capability deficiencies, which were outside the original design requirement, some of these ships were deployed to the Persian Gulf in the early-1990s, with *ad hoc* temporary installations of point defence systems from the not-yet delivered Canadian Patrol Frigates (discussed in more detail below).

The Oberon-class submarines also were starting to show their age in operational obsolescence terms and this led to a 1980s modernization program (the Submarine

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8 CANDIB Oral History Project, interview with Cmdre W.J. ("Bill") Broughton, 4 January 2007.

9 LCdr R. Cyr, "Low Cost Options for Upgrading the Canadian Navy," in *Maritime Warfare Bulletin* (Winter 1985); reprinted in *Maritime Engineering Journal* (April 1987).

Operational Update Programme, or SOUP) that equipped the submarines with updated periscopes and navigation equipment, as well as new sonars, torpedoes and a fire control system with inertial input. Submarine maintenance was a challenge, then as now, and fully one-third of Ship Repair Unit Atlantic hours went to support of the three O-boats. It also was greatly facilitated by Canada being a member of the sizable international 'Oberon Club' which included the UK, Australia, Chile, and Brazil. This provided a broad base of technical and operational expertise upon which to draw, as well as the considerable volume of common spares demand and consequent supply chain stability, and was a significant factor in Canada's ability to support the Oberons – and in its absence, a considerable factor in the subsequent challenges to introduce the later Upholders. Canada maintained a regular technical and operational exchange of Oberon-class submariners with the UK and Australia, and even had a few Canadian naval engineers directly involved with the T2400/Upholder programme while on exchange at the RN's design headquarters at Foxhill near Bath. The ongoing and evident value of these two exchanges eventually led to the establishment of a Canadian Submarine Technical Liaison Officer with Naval Sea Systems Command (NAVSEA) in Washington, DC.

Change: Developing and Delivering the New Fleet

Considering the second thread, change, the beginning of this new post-RCN era also marked a new start in force development, laying the groundwork for the combat core of the new post-steamer fleet.

The first draft of a discussion paper on replacement ships was considered by Cabinet in March 1977, granting approval in December for a six-ship acquisition program. As Peter Haydon has noted,[10] this decision represented a culmination point of the debate on the relative merits of a mixed fleet incorporating smaller more economical vessels for fisheries protection back-up, versus a more homogeneous general purpose fleet of frigate/destroyer-sized vessels. The triumph in this particular instance of 'general purpose' over 'small and cost-effective' left hanging the question of how the remaining fourteen steamers were to be replaced. A June 1980 study entitled Future Ship Study – Follow-on Options to the Canadian Patrol Frigate reviewed options of fleet mix and technology (that is, novel hull forms and propulsion concepts), but came again to the conclusion that the sea-keeping, mobility and operational flexibility requirements of the navy could only be met by a mono-hull frigate-destroyer type ship in the 3,000-5,000 ton range.[11] This conclusion pivoted on two key points: that limiting size was counter-productive due to direct impacts on sea-keeping and mobility; and that small ships designed for primarily regulatory duties could not be made 'combat-capable' and hence

10 Peter T. Haydon, "Choosing the Right Fleet Mix: Lessons from the Canadian Patrol Frigate Selection Process," *Canadian Military Journal* 9:1 (Spring 2008), at: http://www.journal.forces.gc.ca/vo9/no1/10-haydon-eng.asp (accessed 10 November 2010).

11 Referenced in Haydon, "Choosing the Right Fleet Mix," fn 29 as follows: Department of National Defence, *Future Ship Study – Follow-on Options to the Canadian Patrol Frigate*, (no file number) dated 6 June 1980, with covering memo from DM (DND) and CDS to MND, dated 17 July 1980.

were inconsistent with the prevailing strategic concept. All this effort culminated in the nine years 1992-2000, which saw the delivery of four significant elements of the 'new' or current fleet: the Halifax-class frigates, the 'TRUMP'd' DDH-280 Iroquois-class destroyers, the Kingston-class coastal defence vessels, and the lead member of the Victoria-class submarines (more details of each of these programmes follows in the discussion below).

The CPF project represented a further change in ship design and procurement practice from the DDH-280s in that it was decided to have a prime contractor with all subcontracting responsibility – the experience with the 280 program had rendered government-supplied material anathema, a view which still endures. There had been consideration of both the USN approach (in which the navy provides only an operational requirement with scenarios of how they wished the ship to operate) and the Dutch approach (of negotiating directly with a designated lead yard). Ultimately it was concluded that Canada had neither the resources nor the industrial capacity to allow either of these two approaches, and it was decided to provide both an operational requirement and a detailed set of technical requirements/standards. A competitive selection for the initial phase with five consortia bidding eventually was down-selected to two funded project definition competitors: Saint John Shipbuilding Ltd (SJSL) and SCAN Marine. The selection of these two finalists was announced on 8 December 1980, with project definition phase contracts signed in July 1981. Contract design proposals were submitted in October 1982. Evaluation of the proposals and recommendations to Cabinet resulted in approval of the contract in late July 1983, and a formal signing ceremony with SJSL in Saint John, New Brunswick on 15 August, for what officially was known as the Ship Replacement Program, Phase I (SRP I).

While design on the SRP I forged ahead with production targets of first ship by 1989 and sixth by 1992, the department was busy generating proposals for SRP II. It was rapidly determined that the best plan would be to procure a second batch of six CPF based on expectations of learning curve economies – by which SRP II was estimated by the CPF Project Manager in January 1984 at \$2.6B versus the \$3.8B for SRP I (CY\$83/84). Project definition funds for SRP II were approved in April 1984. Following an unsolicited proposal from SJSL, the company was formally requested in September 1985 to prepare an offer for six more frigates. The discussion with the company progressed to the point of formal negotiations in January 1987, while discussion with the Department of Supply and Services (DSS) and Treasury Board Secretariat (TBS) established the viability of amending the CPF contract, rather than having separate contracts. The policy basis for the second batch of frigates was established in the June 1987 White Paper Challenge and Commitment.[12] SRP II was approved 17 December 1987.

The CPF Project initiated a significant change in the maintenance philosophy of the Canadian navy, from the high level of 'artificer' skills that were common to the steamer fleet in both the platform and combat systems disciplines, to 'repair by replacement' (RxR) and 'maintenance by exchange' (MxE). The ship was designed

12 National Defence, *Challenge and Commitment: A Defence Policy for Canada* (Ottawa: Minister of Supply and Services Canada, June 1987).

around these doctrines in response to the increasing complexity of new technology and the drive to reduce numbers of personnel aboard as well as training times.

The CPF Project was a massive undertaking for the Canadian naval engineering establishment, involving the weaving-in of many lessons from previous procurements. The frigate build experience itself demonstrated the value of application of advanced ship-construction techniques in a context of a multi-ship build, illustrating not only the ship-to-ship learning curve effect, but also the institutional learning curve in terms of progressive and significant development of the shipyard's design and build practices. A few significant conclusions for future projects[13] were that:

1. the project procurement philosophy of 'negative guidance' did not allow government and industry to proceed as 'partners' with a vested interest in the implementation of producibility concepts (whether of construction practice, or of design philosophy in terms of a 'robust' ship design using heavier but simpler structure);
2. there was a need for criteria to measure and analyze producibility trade-offs;
3. there was a need to separate lead ship from follow-on ships to allow time for the lessons learned to be folded in; and,
4. an extended programme commitment was important to enable infrastructure development to support advanced production techniques and practices.

Over the number of decades in which the navy had been operating definitively pre-computer-age technology, both in the hull, mechanical and electrical (HM&E) and in the operational domains, technological opportunities and imperatives had been under active exploration and development both in the naval R&D (research and development) establishments and in industry. This period saw the initiation of a number of 'systems' projects (such as SHINCOM, SHINMACS, SHINPADS, and CANTASS[14]) which would form essential capability elements of the eventually chosen CPF design. This systems integration aspect was a significant element of the CPF success – while much of the equipment had been fielded elsewhere, it had not previously been integrated to the extent achieved in the Halifax class. This achievement also demonstrated the value of a strategic approach to defence R&D, integrated with a stable, long-term, naval force development vision.

This period also saw some significant effort in the area of force development and fleet mix studies, which led to the production of the Future Surface Ship Study in 1979. Following from experience with *Bras d'Or*, the navy continued its interest in the potential of advanced naval technologies to achieve operational advantages through platform design, and the pursuit of Small Waterplane Area Twin Hull (SWATH) vessel research at the Defence Research Establishment Atlantic (DREA) was matched with the placement of the first of a continuing series of Canadian exchange officers at the US Navy's David

13 Capt(N) B. Blattman and Cdr V. Archibald, "Canadian Patrol Frigate Construction – Experience Gained," *Marine Engineering Journal* 35 (June 1995), 5-12.

14 Respectively denoting: Shipboard Integrated Communications System; Shipboard Integrated Machinery Control System; Shipboard Integrated Processing and Display (data bus) System; and Canadian Towed Array Sonar System.

Taylor Naval Ship Research & Development Center (DTNSRDC) starting in 1979. Canada embarked on a joint SWATH technology program with the Royal Netherlands Navy (with the US and UK as observers), and became an active member of NATO Special Working Group (SWG) 6 on Advanced Naval Vehicles.

The need for the Iroquois-class to be upgraded had been recognized as early as 1977, and in 1982 a proposal was advanced for preliminary approval for a major mid-life modernization of the four Tribal-class destroyers, known as the Tribal Class Update and Modernization Program (TRUMP). This conversion eventually re-rôled the ships as area air-defence and task group command platforms. The associated combat systems changes were pervasive, including: replacing the signature 'bunny-ear' funnels with one large infra-red suppression funnel; replacing the 5-inch gun with a new Oto Melara super-rapid 76mm gun; installing the MK41 Vertical Launch Missile System (VLMS) with SM2 long-range missiles; and replacing the search and fire-control radars. Other significant changes to the ships included replacement of the cruise engines, a strengthening of the keel, and conversion to a water-displaced fuel system in order to recover stability margins.

An interesting and significant feature of this program was the relationship with the USN and US government in achieving a state-of-the-art area air defence capability. There was some concern in the US regarding Canada's ability to engineer, install and operate the entire system safely.[15] For future commonality reasons, Canada insisted on pursuing the Aegis version of the SM2 (Standard Missile Block 2) rather than accept a unique Canadian modification of the older Tartar long-range missile. Solving the unique problems of the Canadian fire control system controlling the Aegis version of the missile was facilitated by the USN providing access to key scientific and support personnel, and a uniquely Canadian-developed Threat Evaluation & Weapons Assignment (TEWA) software. One further unique Canadian installation problem was the need to rotate the VLMS Mk41 by 90 degrees to fit in the Iroquois-class hull. The Block 2 Standard Missile had not been exported to any other country at the time, and resolution of these and other problems led to increased confidence by the USN concerning Canada's ability to integrate, trial, and operate sophisticated equipment.

The navy had long been considering the particular role of the Naval Reserve and in the late-1980s proposed the Naval Reserve Mine Countermeasures Project (NRMP) to fill a recognized shortfall in coastal defence capability. A proposal was first submitted in May 1988 to build twelve Maritime Coastal Defence Vessels (MCDVs) with a "limited but credible" mine counter measures (MCM) capability. The MCDV implementation project was novel in including provisions for a follow-on in-service support contract (ISSC), under which the eventually so-designated firm, Fenco, would provide both running repairs and depot-level maintenance of the ships and systems (with the limited exceptions of weapons and secure communications equipment). The concept of ISSC arose from lack of up-front commitment to support the MCDVs with existing resources, due to competing CPF, TRUMP and submarine requirements.

15 Tony Thatcher, CANDIB research paper (DHH), 11 January 2009.

The MCDV Project Definition request for proposals (RFP) was released in 1988 and closed in January 1989 with five responses, and project definition (PD) contracts eventually let in July 1989 to Canadian Shipbuilding and Engineering Ltd (CSE) and Fenco Engineers Inc. The PD phase was intended to conclude with an implementation contract let by March 1991. The evaluation process was complete and recommendations for contract award made to government by about May 1991, but it was not until October of that year (after some considerable uncertainty as to whether the decision would respect the evaluation result or other government imperatives) that a decision was made and Fenco announced as the winning bidder. There followed a period of detailed negotiation, reviewing every detail of the implementation proposal and resolving potential ambiguities, before a contract was signed in May 1992. This was particularly necessary due to the nature of some of the systems being procured. The implementation contract was a fixed price bid ($650M(CY)) to supply twelve maritime coastal surveillance platforms capable of 15 knots, and equipped to accept a variety of mission packages also to be supplied: four Route Survey Systems (RSS) using a towed multi-beam side-scan sonar, two Oropesa mechanical minesweeping systems, and one object inspection package (a tethered ROV). The RSS in particular was developmental and there was considerable work to achieve contractual clarity between what was offered and what the expected functionality and characteristics would be. The time and effort invested in achieving this clarity, and in developing Crown-contractor relationships and respect through this dialogue, was in hindsight a significant contributor to the subsequent success of this project.

On the submarine front, in tandem with the SOUP project, the navy had been pursuing replacement submarines for a number of years under various projects: Project M1642 West Coast Submarine Acquisition was commenced in 1978 to obtain a replacement for the west coast submarine HMCS *Rainbow*, disposed of four years previously, and in 1980 was subsumed into Project M1837 Canadian Submarine Replacement Project (CSRP) aiming for a minimum of six submarines to replace the whole of Canada's submarine fleet by the end of the decade. A number of options were explored, including the new British T2400 under development, the Dutch Walrus, the German Type 209, and later a serious review of the potential to establish a joint project with the Royal Australian Navy in replacement of their six Oberons.[16] Cabinet approval to enter project definition was initially expected mid-1986, with subsequent selection of two finalists for funded project definition by 1988, contract by early-1990, and delivery of four vessels between 1995 and 1999.[17] The submarine replacement was expected to be

16 Three Canadian officers had gone to work with the Australian team soon after the project office was established in February 1982, remaining until 1985. In 1990, following the end of Canada's "flirtation with nuclear submarines," the Australian Submarine Corporation (ASC) set up an office in Canada to promote the Collins Class, closing in 1993 when it became apparent that Canada would likely buy second hand. See Peter Yule and Derek Woolner, *The Collins Class Submarine Story* (Cambridge University Press, 2008), 30, 201, and 203 (the quote in this note above is from 203).

17 Martin Shadwick, "Canadian Submarine Acquisition Programme," *Canadian Defence Quarterly* (Spring 1986), 6-8.

part three of the fleet-wide Ship Replacement Project – SRP III.

In 1985 Project M1837 was re-designated the Canadian Submarine Acquisition Project (CASAP)[18] and direction was given to provide a full analysis of the requirement (including examination of 'the nuclear option') and not to just assume the replacement of old equipment. This was the leading edge of a fundamental rethink of defence priorities and objectives, particularly with respect to Arctic operations and sovereignty.[19] Following the summer 1986 appointments of Perrin Beatty as Minister of National Defence and Paul Dick as Associate Minister, CASAP was rapidly overtaken by what in hindsight one can only characterize as a chronic relapse into the recurrent fascination with the nuclear submarine option, notwithstanding all historical indicators that the government would be unlikely to sustain the funding commitment to realize this goal.[20] In light of subsequent events, it is ironic that the 1987 Defence White Paper which launched this diversion was entitled Challenge and Commitment.[21] A challenge there was, indeed.

With the publication of the new White Paper, the project objectives were again recast and the project placed under the direction of a newly-established Chief of Submarine Acquisition at the rear-admiral level (actually, the Chief of Maritime Doctrine and Operations, re-tasked to a full-time focus on submarines).

The scope of this paper cannot do justice to the full story of the SSN project in all its varied technical, economic and political aspects. As a cautionary tale, however, it did and does illustrate the perils of a combination of instability in strategic assessment and intent, compounded by optimism with respect to ultimate costs. Even at the time it was clear that there were significant doubts regarding the national ability and will to follow through on the financial commitments inherent in the new Defence White Paper.[22] Indeed, even while the French and British were soon competing to win Canada's hand in this venture, colleagues in the USN were seriously questioning whether Canada properly knew the costs of what it was attempting. The end came swiftly and unexpectedly, when a premature leak of the April 1989 Budget broke the news of wide-ranging cuts, including the SSN project. That ADM(Mat) and the Chief of the Maritime Staff (CMS) were dining (separately) with officials of the opposing teams the very night of the

18 M.J. Craven, "A Rational Choice Revisited – Submarine Capability in a Transformational Era," *Canadian Military Journal* 7:4 (Winter 2006-2007); on-line at http://www.journal .forces.gc.ca/vo7/no4/craven-eng.asp, accessed 04 January 2011.

19 As Lajeunesse has noted, "The acquisition of a large fleet of SSNs was thus totally out of character for the Canadian Navy. This radical shift in hardware can only be explained by a radical shift in objectives." Adam Lajeunesse, "Sovereignty, Security and the Canadian Nuclear Submarine Program," *Canadian Military Journal* 8:4 (Winter 2007-2008); on-line at http://www.journal.forces.gc.ca/vo8/no4/lajeunes-eng.asp, accessed 04 January 2011.

20 S. Mathwin Davis, "It Has All Happened Before: The RCN, Nuclear Propulsion and Submarines, 1958-68," *Canadian Defence Quarterly* (Autumn 1987), 34-40.

21 *Challenge and Commitment*, *op. cit.*

22 R.B. Byers, "The 1987 Defence White Paper – An Analysis," *Canadian Defence Quarterly* (Autumn 1987), 11-22.

leak suggests that budget secrecy was in all other respects quite tight.

In the middle of the CPF and TRUMP project implementation, the Canadian navy was faced with an urgent operational deployment, which reminded everyone that urgent calls on deployable capability do not necessarily respect the planned timelines of new capability delivery. Following the invasion of Kuwait by Iraq on 2 August 1990, the Mulroney government had decided by10 August to support the multinational effort in the Gulf, and HMC Ships *Athabaskan*, *Terra Nova,* and *Protecteur* were ordered to be made ready for sea to deploy as soon as possible for what became known as Operation Friction (the more commonly known US titles are Operations Desert Shield / Desert Storm). In the space of the following two weeks, approximately 100,000 man-hours were poured into these three ships to fit systems such as four CIWS mounts amongst the three ships; Harpoon anti-ship missiles in *Terra Nova*; a 3-inch/50 gun in *Protecteur*; and SATCOM, SHIELD decoy systems, mine avoidance sonar, 40mm Bofors anti-aircraft guns and 50-calibre machine guns in all three. This initial deployment was to be followed by the rotational deployment of HMC Ships *Huron* and *Restigouche* (*Protecteur* underwent an in-theatre crew exchange concurrent with an extended rest and maintenance period). Much of this rapid deployment of capability was made possible both by the fortuitous availability of combat systems elements awaiting installation in the CPF, TRUMP and MCDV projects, as well as the strategic capability of the naval dockyard Ship Repair Units (SRUs).[23] Sustainment of the capability in-theatre was dependent upon both extensive in-theatre contracted support and home-supported mobile repair parties.

The 1990s witnessed an ongoing struggle to sustain the old O-boats in the midst of continuing apparent indecision as to whether there was to be a replacement submarine at all. The fact that the previous Project M2549 Canadian Patrol Submarine Project (CPSP) had been renamed to the intentionally ambiguous 'Submarine Capability Life Extension' Project was not taken to be especially propitious, and the acronym SCLE was commonly pronounced "sickle" or "sickly" according to the mood. At long last, in April 1998, the government announced the intention to move on the long-delayed, on-again/off-again submarine acquisition. Having courted the British *Upholder* option on-and-off for four long years, the project team were suddenly given four months to get into contract. The *Upholder* purchase was significant in being the first time that Canada had purchased a class of second-hand warships under a contractual arrangement.[24] There was thus little prior practice to go on, and indeed the UK Project Manager was fond of

23 See LCdr Imran Mirza, "Crisis in the Gulf – Making Operation Friction Happen," *Maritime Engineering Journal* (January 1992), 5-8; and LCdr R.B. Houseman and Lt(N) B.J. Corse, "Operation Friction II: Preparing HMCS *Restigouche* for the Gulf, Part 1", and Lieutenants(N) Chris Hargreaves and Frank Pearce, "Part 2", and LCdr F. Ruttan & Lt(N) Pearce, "Part 3", *Maritime Engineering Journal* (April 1992), 5-15.

24 There were similar-but-different circumstances in the past: the carriers *Warrior* and then *Magnificent* were 'loaned' to the RCN for the period 1946-57 before being returned to RN control; *Bonaventure* was bought by Canada while still under construction; and the USN loaned the submarine *Grilse* (ex-*Burrfish*) to the RCN for a five-year period. The only similar circumstance was the lone purchase of the USN submarine *Argonaut*, which served as HMCS *Rainbow* 1968-74.

asserting (when it suited him) that this was in fact not a contract, but a government-to-government 'arrangement'. Notwithstanding the lack of time, the form of the contract was conceptually simple: the submarines were to undergo a 'reactivation work-period' (refit) to a standard acceptable to the Royal Navy. The submarine would then be taken to sea for trials and deep dive qualification with the Canadian crew under a Royal Navy commanding officer (effectively, 'on exchange'). Once the submarine and the crew together passed their technical and operational certification to the satisfaction of the RN Flag Officer Submarines (FOSM) staff, the boat and crew together were signed over to Canada and to their Canadian CO at a renaming and acceptance ceremony. This arrangement had a number of advantages, key among them that the costs and contracting for reactivation (with whatever arisings occurred) was strictly between the UK Ministry of Defence and the Vickers Shipbuilding & Engineering Ltd shipyard in Barrow-in-Furness (VSEL, later to become BAE Systems). Notwithstanding this, reactivation turned out to be much more of a challenge than either the MOD(UK) or VSEL had expected, and it was indeed fortunate that initial pressures in Canada to amend the reactivation model were effectively resisted.

From the early-1980s the framework for the fleet replacement extending out over 30 years included a replacement for the AORs. A timely operational support ship (OSS) replacement for HMC Ships *Protecteur* and *Preserver* would have started planning in 1989, with contract definition commencing in 1992, contract let in 1994, and delivery between 1998 and 2002. As it was, the tortured history of this requirement is illustrative of requirements formulation as both the pivot and the Achilles heel of the ship design process.[25]

Originally conceived in the 1980s by MIL Systems Engineering under the name of SMART (Strategic Multi-Role Aid and Replenishment Transport),[26] the design was initiated as an internal study that the company believed the navy might have an interest in. The SMART ship had a number of limitations (at 18,800 tonnes, with only two RAS stations, and at 6500 tonnes only half the fuel capacity of the existing Protecteur class), but featured the introduction of 2444 Ro-Ro lane metres and 200 TEU container cargo capacity suitable to the intended multi-task usage. Although the solution was not deemed sufficient, the combination of capabilities was clearly of interest, and by 1994 the concept had been adopted and evolved in navy hands into the Multi-Role Support Vessel (MRSV), a little larger at 22,000 tonnes with now 60 percent of the existing cargo fuel capacity. It still had only two RAS stations, but now had 3305 lane metres of Ro-Ro capacity.

By 1997, in response to increased perception of the force multiplier effect and

25 It has been said that the hardest thing about ship design is designing the requirement – if the requirement is complete, internally consistent, feasible and affordable, then all the rest is 'just' engineering and logistics. If the requirement is not all of these things, then no amount of engineering and logistical brilliance can solve the problem.

26 J.R. Williams, "A History of the Canadian Industry Warship Design Capability 1945-2002," unpublished paper in archives of the Canadian Naval Technical History Association, section 3.2, 50/86.

experience supporting sealift and forces ashore as in the Somalia deployment, this concept had evolved yet further (with another name change, to Afloat Logistics Support Concept or ALSC).[27] Increased emphasis on participation in combined and joint operations of limited scope led to definition of five main roles for the vessel: underway support to naval forces at sea; in-theatre support to joint forces ashore; sealift; humanitarian operations; and sovereignty enforcement and surveillance. The Defence Planning Guide of 1997 indicated the intent to start detailed planning of the ALSC project in 2000. At this point, there was internal direction to 'fast-track' ALSC.

By the first years of the new millennium, the ALSC concept had grown to 35,000 tonnes capable of 21 knots, ice-capable to 70 cm in order to be able to penetrate the St Lawrence to Montreal 12 months a year, with 10,000 tonnes of cargo fuel and 500 tonnes of aviation fuel, 500 tonnes of munitions, a full four RAS stations, two helicopter spots and hangar space for four. The ship was to have 2500 lane metres of Ro-Ro capacity, as well as cranes, ramps and landing craft operating out of a well-deck offering a variety of cargo loading and discharge options. In addition, ALSC was intended to be able to simultaneously serve two of three additional logistics support roles: a limited (75 person) command and control function in support of troops on the ground; a medical facility of 60 beds; and a rest and recuperation zone for troops operating in a difficult theatre.[28]

In 2003 the project was renamed the Joint Support Ship (JSS) Project to emphasize the 'Jointness' of the capability requirement, but when the eventual reality-check set in the requirement was re-cast as a reduced JSS-'lite' capability. This attempt proceeded into funded project definition in 2006 before coming to an impasse in spring 2008 when both project definition competitors were unable to provide cost-compliant implementation bids. There was some irony that, while this JSS-lite capability was in the project definition phase, there was within NDHQ some discussion of a programme combining an AOR capability and a separate 'big honking ship' (BHS, a term coined by the then-Chief of Defence Staff for a LHD-type amphibious support ship), the latter a capability intended to support the embryonic concept of a Standing Contingency Task Force (SCTF). This notion too met an affordability reckoning. In the aftermath of both the BHS discussion and the failed JSS-lite procurement, the constituency for the evolved joint requirement faded.

The final iteration of this extended quest to sustain the RCN's AOR capability (either with or with elements of 'jointness') commenced in July 2010 when the government announced the intent to consider two different solution paths: a cost-constrained capability-based new design versus a Military-off-the-shelf (MOTS) design to be built under license. The decision was subsequently made to go with the MOTS option based on a modification of the German FGS *Bonn* design (itself a development of the type 702 Berlin class).[29]

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27 Irvine, Bruce, "Afloat Logistics and Sealift Capability for the Canadian Navy," *Canadian Defence Quarterly* (Summer 1997).

28 Yves Biron, « Les ravitailleurs multi-tâches canadiens – Leur passé et leur avenir – Le projet ALSC », École d'état major des forces canadiennes, le 9 mai 2003.

29 Public works and Government Services Canada, "Backgrounder: Joint Support Ships (JSS),"

Through the middle of the MARCOM era, the Canadian navy faced a tremendous challenge in terms of simultaneous project development and implementation demands, compounded and frustrated by people and financial resource shortages. This led to a number of change initiatives related to trade and organizational structures, mandates and philosophies. The Maritime Other Ranks Production Study (MORPS) was initially organized in 1977 to address recruiting and retention through attention to rank-to-rank ratios to improve promotion flow and selectivity and to gradually improve sea-shore ratios over an individual's career. On the officer side, in 1985 a change to the Maritime Engineer (MARE) officer classification was introduced to formally recognize sub-classifications of MARE and to allow recruiting, selection and tailored training of these specialties to meet the navy's project needs. The new MARE Classification thus had five identified designations: 44A – Basic MARE classification qualified; 44B – Marine Systems Engineer; 44C – Combat Systems Engineer; 44D – Naval Constructor; and 44E – Naval Architect. The officers of these sub-classifications all competed within one career classification, which led to subsequent debate regarding proportionality of promotion rates and some subsequent further evolution of the naval engineer career field. Career structure was only one of the challenges facing the naval engineering branch in the 1980s – the other was recruiting, which led to the establishment of a 'MARE Get Well' project. This project was driven fundamentally by the demands of the major capital projects of the time and led not only to the restructuring of the Branch as noted above, but also to a very determined and successful recruiting drive. From 450 naval engineer officers in 1982, the branch expanded to over 650 by 1994.

Personnel structure changes were matched and followed by organizational changes. Although Canada did not go as far as our Commonwealth allies in closing or privatizing naval Dockyards, resource constraints drove some significant changes. The coastal engineering and maintenance functions were not immune to pressures for rationalization; in the mid-1990s, the SRUs, NEUs and FMGs were consolidated into a single unit, the Fleet Maintenance Facility (FMF) on each coast. This amalgamation was accompanied by a substantial reduction in the ship repair workforce (by about half), along with a fundamental reorientation of the work apportionment. Henceforth, the FMFs would concentrate on second level running repairs in direct support of fleet operational tempo and deployments, while all third-level work (refits and overhaul work) would go by default to civilian contract. There was, in addition, an initiative to achieve Most Efficient Organization (MEO) status for the FMFs in order to establish a clear case against recurring suggestions of privatization. This did run somewhat counter to the notions inherent in the work apportionment, which relied on the contractors to become increasingly efficient at the more predictable, scheduled refit work, while the FMFs were expected to be effective at managing the more volatile and urgent operational support work. This distinction would become more evident through the unfolding of later events.

Sustainment: Bridging from the Old Fleet through the New Fleet to the Next Fleet

31 May 2013, at: http://www.tpsgc-pwgsc.gc.ca/app-acq/sam-mps/dinsi-bkjss-eng.html, accessed 19 Sep 2014.

The first ten years of this new millennium can be characterized as being concerned with sustainment, both in immediate operational and extended capability terms. From the outset of the decade, sustainment of operations was a high priority with an unexpected high demand in supporting the mission fit and repair requirements for ships supporting Operation Apollo (the Canadian term for the contribution to the war on terrorism, better known as the American Operation Enduring Freedom). In the first two years following the 9/11 terror attacks, almost every major platform in the Canadian navy deployed at least once to the Persian Gulf, reflecting a very considerable accomplishment in the naval dockyards (the exceptions being HMC Ships *Athabaskan* and *Ville de Québec* which were in the course of contracted major refits). There was also a considerable focus on sustaining two particular combat capabilities that will bridge the navy between the fleet of the present and the fleet of the future: the Halifax-class frigates and the Victoria-class submarines. There is a particularly symbiotic relationship between these two core capabilities, as the *Victoria* class achievement of steady-state full operational capability is an essential counterpoise to the reduced operational availability of the frigates as they pass through their mid-life upgrade.

The 2001-03 experience of Operation Apollo demonstrated by contrast with Operation Friction how far the Canadian navy had come in being able to field a credible naval capability. This was apparent not only in the initial capability of the Halifax-class frigates, which now were the core of the Canadian naval contribution, but also in the ability to modify those frigates and the Iroquois-class command ships to effectively integrate with USN carrier battle-groups.

Op Apollo also demonstrated once again the value of the naval dockyards (the Fleet Maintenance Facilities or FMFs) as a strategic asset, in being able to quickly mobilize engineering and production resources, both in support of the initial deployment of ships with required mission fits, and in the subsequent fielding of mobile repair and support parties. As just one particular example, the development and fielding of a deployable ranging/degaussing system led to two Victoria-based FMF *Cape Breton* civilian employees spending enough time in theatre to earn the South-West Asia Service Medal (SWASM).

The Halifax Class Modernization (HCM) Project is an interesting case study of how complex and lengthy the project approval process had become. The twelve frigates had all been commissioned within a four-year period from June 1992 to September 1996, and thus would all need modernization within a compressed period of time around the 15-year projected lifespan of the combat system. Initiated in November 2001, the Frigate Equipment Life Extension Project (FELEX) was a project to investigate changes in weapons, sensors, defensive systems, C4ISR equipment, hull, engineering, propulsion, and other supporting equipments to ensure serviceability for 15 years beyond half-life. From the beginning there was concern about management of this wider modernized Halifax class work package, and in August 2003 the Project Manager suggested that an effective programmatic approach would be to combine the traits of a traditional project organizational construct with those of a network (or matrix) organization. Thus, the FELEX project would actually host individual systems modifications developed as engineering changes. This was effectively lining up the mid-life refit as a larger and more than usually comprehensive docking work period (DWP) comprised of planned maintenance, corrective maintenance, and engineering change (for both capability upgrade and obsolescence management purposes).

The final evolution of the procurement strategy in December 2006 proposed a 'multi-ship contract' approach for the mid-life refits (MLRs) and preceding/following docking work periods (DWPs), and a Combat Systems Integrator (CSI) prime contractor concept for both the implementation and software in-service support for the complex combat systems core of the project. The multi-ship DWP and CSI contracts eventually were signed in March and November 2008 respectively.

At the time of this conference, the navy was well into the implementation of the modernization project (with the lead ship, *Halifax*, having just entered the shipyard) and daily lessons were being learned. A predictable one is that, when one contract fixed-price, prime responsibility, one does not retain system selection rights. Another lesson on the project side is that system performance requirements are difficult to prove and enforce at a sufficiently early stage of development that intervention can effectively change the course of events – thus, the system requirements review stage is an exceedingly important stage of contract reconciliation. However, notwithstanding these points, the HCM/FELEX project has been regarded as a notable success – at the time of printing in late 2014, HMC Ships *Halifax* and *Winnipeg* are well into extended trials while *Calgary* and *Fredericton* are nearing completion of acceptance trials and are being readied for operational deployments in 2015.[30]

Returning to submarines, the original delivery intentions for the Victoria class had been to accept the first one (the former HMS *Unseen*) in April 2000, and the other three at six-month intervals thereafter. Resolution of the vicolets issue[31] delayed acceptance of *Victoria* until 6 October 2000. The remaining boats (*Windsor* / *Ursula*, *Corner Brook* / *Unicorn*, and *Chicoutimi* / *Upholder*) were delivered with further delays (July 2001, February 2003, and October 2004 respectively).

These delays in introducing the Victorias were only the beginning of a succession of challenges. Some of these fell into the category of unanticipated complexity in the step from the post-Second World War-era *Oberon* technology to the much more stringent

30 A further measure of the success of this project is that Lockheed Martin Canada and Seaspan/Victoria Shipyards have partnered and won the contract to execute a similar combat systems upgrade for the two frigates of the Royal New Zealand Navy.

31 A 'vicolet' is a standard Vickers Shipbuilding and Engineering Ltd (VSEL) production detail for 'T' joints in high pressure welded piping systems. In the reactivation of the Upholder Class submarines prior to transfer to Canada, it was discovered that, in the three follow-on boats (*Unseen*, *Ursula*, and *Unicorn*) there were a significant number of flawed welds in the installation of these vicolets. Under the agreement of 'reactivation to a standard acceptable to the Royal Navy', these vicolets were all replaced at UK expense, albeit with an impact on contracted delivery dates. A further impact on the programme was that the re-work all had to be conducted to the extant UK submarine welding quality assurance standard which was more exacting and intrusive (in terms of required radiography) than the original build QA standard.

modern norms of submarine safety certification. Additionally, it had not been properly understood what were the consequences of the submarines never having fully completed their introduction into the Royal Navy (for example, in terms of not fully exercising the planned maintenance schedule nor fully establishing the supply chain and sparing levels). An additional complexity was the under-estimation of the time required to implement the Canadianization Work Period (CWP) in the naval dockyard in Halifax.

A second category of significant impacts on the submarine introduction resulted from un-forecasted events. These included: the advent of the Operation Apollo / Enduring Freedom major ship deployments with attendant impacts on dockyard priorities delaying Victoria's Canadianization work period; the discovery and repair of critical valve seat cracking in the diesel hull exhaust and back-up valves (DEHBUVs, two 1.5-tonne castings in the crown of the pressure hull); and the tragic 5 October 2004 fire and loss of life in *Chicoutimi* which led to a six-month moratorium on submarine operations while the Board of Inquiry determined causes and potential class implications.[32]

Following this, while the west coast dockyard was wrestling with *Victoria*'s extended docking work period, DND was laying the groundwork for long-term industry support to submarine maintenance by competing a 15-year Victoria Class In Service Support Contract (VISSC). In order to ensure continuity of work for efficiency and learning curve benefits, this contract was competed to select a single contractor and, after the delay of a lengthy legal challenge, the contract was signed 30 June 2008 with the Canadian Submarine Management Group (CSMG Inc.), a subsidiary of Babcock International Group PLC, teamed with Seaspan/Victoria Shipyards.

The other dimension of sustainment was reflected in ongoing force development activity during this period, particularly focusing on the replacement of the AOR capability, the introduction of a new capability to project national presence and sovereignty enforcement into the Arctic, and projection of a class of surface combatants to eventually replace the Halifax and Iroquois classes. The first of these projects was the re-launched Joint Support Ship (JSS) project, while the latter two were respectively the Arctic Offshore Patrol Ship (AOPS) and the Canadian Surface Combatant (CSC). The various histories of all of them demonstrate the exceedingly indirect nature of force development and project evolution. The further detailed development of the fortunes of the JSS, AOPS, and CSC projects should be more properly covered in, hopefully, a future Part IV to "An Engineer's Outline...". However, it would be appropriate to conclude this section with a few words regarding a strategic development of great significance for the continuation of this story – the National Shipbuilding Procurement Strategy (NSPS).

The existence of and the requirement to mitigate the adverse effects of the boom and bust cycles of Canadian naval and national shipbuilding activity have been long

32 See Peter T. Haydon, "The *Chicoutimi* Accident: Lessons Learned and Not Learned," *Canadian Military Journal* 6:3 (Autumn 2005): http://www.journal.forces.gc.ca/vo6/no3/maritim-marin-eng.asp, accessed 15 September 2014. The *Chicoutimi* Board of Inquiry is at: http://www.crs-csex.forces.gc.ca/boi-ce/rp/hmcs-ncsm/index-eng.aspx, accessed 15 September 2014.

recognized and frequently commented upon.[33] In June 2010 the government announced the intention to adopt a strategic approach to resolving this problem in supplying ships for Canada's federal fleets (the RCN and the Coast Guard). Under the NSPS the government proposed to establish, by competitive selection, strategic relationships with two Canadian shipyards – one to build Canada's combatant vessels for the next 30 years (CSC and AOPS), and the other to build the 'non-combatant' vessels (the RCN's JSS and Coast Guard science vessels, buoy tenders and icebreakers). In October 2011 it was announced that Irving Shipbuilding Inc. of Halifax and Vancouver Shipyards Co. Ltd of Vancouver were selected respectively for the combatant and non-combatant packages.[34] At the time of printing. design work is underway in both yards for ships in their respective packages.[35]

Currents of Dependence, Independence and Inter-dependence in Commonwealth / Allied Naval Technical Interaction

The foregoing has emphasized the progression of the Canadian naval engineering story in terms of continuity, change and sustainment, but it can equally be viewed through the triad of dependence, independence, and interdependence.

There is no question that at the beginning of the era in question, there was still a very strong engineering link to the Royal Navy. Based on common systems, the RCN did a significant portion of its engineer officer training at the Royal Naval Engineering College (both marine systems engineers and, until the mid-1970s, weapons systems engineer). Even after the commonality of systems selection had passed, there continued this link of marine systems training based on the shared engineer officer structure and traditions. In other areas, the Canadian naval engineering branch borrowed equally from our two closest allies – naval architects were trained (in almost equal numbers) either with the Royal Corps of Naval Constructors MSc program at University College London,

33 Michael A. Hennessey, "The Rise and Fall of a Canadian Maritime Policy, 1939-1965: A Study of Industry, Navalism and the State," PhD Thesis, University of New Brunswick, February 1995; also R.W. Greenwood, "Globalization, Maritime Strategy, and the Survival of the Canadian Maritime Industry," CFC/NSSC 7 Paper, 28 May 2005.

34 http://www.tpsgc-pwgsc.gc.ca/app-acq/sam-mps/snacn-nsps-eng.html accessed 19 Sep 14.

35 As this journal goes to print in late 2014, the Government of Canada has just announced that HMC Ships *Protecteur* and *Preserver* will be paid off in 2015, following the major engine room fire suffered by the former in February 2014 which complicated the continuing sustainability of the class. The same announcement noted that two of the remaining three DDH-280s (*Iroquois* and *Algonquin*) also would be paid off, for similar class-sustainability issues. These were provided in the context of pointing to progress on the AOPS building contract process, with the naming of the lead ship of the AOPS as HMCS *Harry DeWolf*. See Government of Canada, "Royal Canadian Navy Begins Transition to the Future Fleet," 19 September 2014, at: http://news.gc.ca/web/article-en.do?nid=885979, accessed 20 September 2014; and Royal Canadian Navy, "RCN's Arctic/Offshore Patrol Ships named Harry DeWolf Class, at: http://www.navy-marine.forces.gc.ca/en/news-operations/news-view.page?doc=rcn-s-arctic-offshore-patrol-ships-named-harry-dewolf-class/hzvlsvze, accessed 20 September 2014.

or with the USN Engineering Duty Officer '13A' program at the Massachusetts Institute of Technology. All these training contacts, and those developed through subsequent technical exchange postings between the Canadian Navy, the RN, and the USN (at Foxhill / Abbey Wood in Britain, at NAVSEA and various US naval shipyards, and at the David Taylor Naval Ship Research & Development Center) ensured a lively exchange of views and information regarding naval engineering and warship procurement, and a generous sharing of RN and USN general ship specifications ('GenSpecs') as a basis for the development of indigenous warship design standards.

The design of the 'Cadillac' (St. Laurent-class destroyer escort) family of ships was very much driven by British design philosophy; albeit somewhat leavened by some North American equipment selection and supply, the expertise content was significantly UK-sourced. Even so, there was already an embryonic impulse to a recognizably distinct result – Constructor Commodore Rowland Baker, designer of the St Laurent class on loan from the Royal Corps of Naval Constructors, is noted to have acknowledged that "(his) anxiety to have an appearance different from the British could be dismissed as rank Canadianization."[36] This Canadianization left its imprint on Canadian naval engineering traditions, not only in its artefacts, but also on the industry as a whole, due to the numbers of exchange officers, shipbuilders and engineers of that generation (and since) who decided to remain in Canada after their immediate exchange duty finished, working either in the navy directly, in the public service, or in industry.

In the warship programmes that followed the steamers – the Iroquois and Halifax classes – this British element of Canada's naval engineering foundation was balanced by the import of ship-building and systems integration expertise from the USA and other nations. Equipment selection tilted more from British towards American systems and other international sources, even while the resulting ships themselves continued to be distinctly recognizable and uniquely Canadian in terms of innovations pushing new capability through systems integration.

This phase of developing independence from the RN 'mother-ship' traditions and expertise was also reflected in the development of national capabilities in the naval R&D and dockyard skills to maintain submarines. Following the RN cessation of Oberon operations, the continuing development of indigenous capabilities in the Canadian naval R&D labs laid the basis for subsequent material trouble-shooting with the Victoria class. This independent capability has in turn positioned the Canadian navy to provide reciprocal technical support to the RN, RAN, and other navies in terms of a range of submarine engineering issues, such as NAB (nickel-aluminium-bronze) valve re-certification, DEHBUV valve-seat cracking, oxygen generation candles, and escape tower hood inflation systems.

It is an obvious thought that the pressure for interoperability at sea leads to interdependence, not only in terms of procedures but also in terms of characteristics of communications and command and control systems. Thus communications mission-fits formed a large part of the challenge of preparing Op Apollo ships for integration with USN carrier battle groups. Similarly, interoperability was a key objective in the selection

36 D.K. Brown, *A Century of Naval Construction* (London: Conway, 1983), 352.

of an upgrade path for the submarine bow sonar system, both in benefiting from the open architecture design allowing flexibility in future system capability growth, as well as permitting operational exchange of acoustic data with the USN.

Taken together, these developments exemplify the ultimate phase in the evolution of Canadian naval engineering: interdependence through interoperability and collaboration.

Conclusions

The current workhorse of the Canadian fleet, the Halifax-class frigate, is in many ways the technological symbol and emblem of the era, in terms of the extended force development discussions and R&D; in terms of the challenges of the programme; and in terms of the ultimate operational success and versatility of the ship design itself.

The programme challenges included the significant systems innovations that were attempted and achieved in the design and production of the ship, ushering in an age of systems integration. This also included, notwithstanding clear initial intentions otherwise, the perpetuation of the traditional boom and bust cycle of shipbuilding which had posed significant programmatic difficulties in the past, and will again challenge ship availability in the coming first decade of the Royal Canadian Navy's second century. This lesson has been identified and a solution proposed in the National Shipbuilding Procurement Strategy (NSPS) – time will tell how successful this initiative will be in addressing the particular issue of procurement stability.

The start of the ship replacement programme in the 1980s clearly demonstrated the criticality of the human resource dimension in meeting the technological demand. It became necessary to rethink priorities and deeply-held beliefs and convictions about the appropriate training and employment of engineers and technicians, with resultant changes to trade structures. The fact that these trade structures have changed again reflects both a natural and appropriate response to the continuing and converging developments in the technology domain, as well as the continuing pressures of a shrinking demographic pool, inspiring ongoing attempts to accelerate the throughput of the training systems and to increase the versatility of the output.

Over the period, there has been an evolution in the sense of purpose of the engineering branch. While support of operations at sea in the sense of fielding capability is clearly the most immediate aim of the initial training and employment, it is recognized that the ultimate goal is long-term sustainment of naval capability at sea. This objective has wide ramifications throughout the whole of the naval engineering and maintenance system – inside and outside DND – as it is apparent that, not only does the ship as a system need to be designed for sustainability in terms of the full range of resources available and affordable, but also that the supply chain and industry itself needs to be considered as an integral part of the system. Thus ship acquisition programmes need to be approached, not as silos of individual platform replacement programs, but as part of a rolling wave of broad-based naval capability sustainment activity.

In overall retrospect, looking back over a hundred years of the ebb and flow of naval materiel issues and challenges, and comparing this four-decade MARCOM period with the preceding six decades of the RCN era, a number of themes are surprisingly recurrent, notwithstanding the march of technology.

The definition and delivery of naval platforms historically has oscillated between the twin imperatives of the march of technology and the evolution of the perceived strategic threat; this is the classic 'technology-push' versus 'requirements-pull' dilemma. Increasing adaptability in platforms has seen the platform capability progressively become more dependent on the integration of the whole rather than the component capabilities of the individual elements. From the initial acceptance of old RN warships, to the indigenous production of British designs, to production of Canadian-designed ships with (largely) foreign equipment, the significant Canadian naval engineering input has been towards increasing sophistication and innovation in the systems integration of the whole.

The naval engineering trades and organizations, the dockyard support facilities, the governmental departments and mandates, and the civilian industry itself, have also all evolved considerably throughout this period in response to shifting perceptions of the stability and commitment of national purpose with respect to the navy as a national institution. Admiral Goldrick captured this point very succinctly in his essay contribution to this volume when he suggested the subtle but distinct difference between building a Fleet and building a Navy – the one a temporal materiel construct; the other an enduring institution and capability. This purpose has not always been constant and the history of Canadian naval engineering has a significant trail of boom and bust; great highs of technological innovation, and lows of disappointed opportunities and retrenchment.

Overall, however, to echo Jim Knox, the story of naval engineering in Canada is indeed one of evolution – well-rounded and well-founded versatility followed by successful adaptation.

To return to the initial theme, this characteristic is epitomized in the Halifax-class frigate. At the time of presenting this paper to the conference in 2010, HMCS *Halifax* was entering her mid-life modernization refit, and the author reflected that she was older than was HMCS *Saskatchewan* when he joined her as a sub-lieutenant for Engineer-Officer-of-the-Watch training in 1979, notwithstanding that the Halifax class are still considered by many as 'the new ships'. The significant difference is that the Halifax class are, even before modernization, far more capable than were the steamer fleet even after their midlife refit in the 1970s. That this is possible, for a ship conceived in the midst of the Cold War and reaching mid-life in the post-9/11 world, is a testament to the strong threads of continuity and adaptability in the naval engineering tradition that has supported and sustained the Royal Canadian Navy through its first century.