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LEARNING FROM EXPERIENCE

VOLUME IV

Lessons from Australia's *Collins* Submarine Program

Prepared for Australia's Department of Defence

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Preface

Large, complex design and construction programs demand personnel with unique skills and capabilities supplemented with practical experiences in their areas of expertise. This is especially true in designing and constructing naval submarines. These vessels require that unique engineer and designer skills be nurtured and sustained and that program managers at all levels be trained and educated so as to create the pool of knowledge and experience to conduct a successful program.[1] In the past, key technical and management personnel in the submarine community were nurtured and sustained by numerous sequential design and acquisition programs. By participating in one or more programs, personnel gained experience to be the leaders in future programs.

But as the operational lives of submarines have lengthened and as defense budgets in most nations have been constrained, new submarine programs are occurring less frequently. Today, there are substantial gaps between new program starts, resulting in fewer opportunities for personnel to gain the experience they need to manage complex processes and make informed decisions than in the past. Future managers of new programs may not have the benefit of learning from the challenges faced and issues solved in past programs.

Recognizing the importance of documenting and imparting experiences from past submarine programs, the Head, Maritime Systems Division, in Australia's Defence Materiel Organisation asked the RAND Corporation to develop a set of lessons learned from the *Collins* submarine program that could help inform future program managers. This document describes important lessons learned from the *Collins*

1 See Schank et al., 2005; Schank et al., 2007.

program. Other volumes in the series provide lessons from the United States and United Kingdom submarine programs and a summary of lessons across the three countries:

- MG-1128/1-NAVY, *Learning from Experience, Volume I: Lessons from the Submarine Programs of the United States, United Kingdom, and Australia*
- MG-1128/2-NAVY, *Learning from Experience, Volume II: Lessons from the U.S. Navy's* Ohio, Seawolf, *and* Virginia *Submarine Programs*
- MG-1128/3-NAVY, *Learning from Experience, Volume III: Lessons from the United Kingdom's* Astute *Submarine Program*.

This case study does not focus specifically on the history of the *Collins* program—an excellent description of the program was documented by Peter Yule and Derek Woolner in *The Collins Class Submarine Story: Steel, Spies, and Spin* (2008). Rather, we focus on the problems and successes in the program and the reasons behind them. We draw on the Yule and Woolner historical overview as well as a wide range of literature on the *Collins* program and other submarine design and construction programs. This literature review is supplemented by interviews that we conducted with more than 25 key Australians and Americans involved in the program.

The document should be of interest to the naval defense planning, acquisition, logistics, operational, maintenance, technical, and legislative communities and their contractors in the United States, Australia, and United Kingdom.

This research was conducted within the Acquisition and Technology Policy Center of the RAND National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, the Unified Combatant Commands, the Navy, the Marine Corps, the defense agencies, and the defense Intelligence Community.

For more information on the Acquisition and Technology Policy Center, see http://www.rand.org/nsrd/ndri/centers/atp.html or contact the director (contact information is provided on the web page).

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Summary

To design and construct conventional or nuclear-powered submarines, modern navies and shipbuilders need personnel and organizations that possess unique and specialized skills and expertise. Submarines are among the most complex systems that countries produce, and the technical personnel, designers, construction tradesmen, and program managers who work on them represent pools of knowledge that take years to develop and cannot be replicated easily or quickly.

In years past, the pace of construction on replacement submarines was quick enough in most countries that key technical and management personnel in submarine programs were able both to work on a stream of successive submarines and to pass their knowledge on to personnel who followed in their footsteps. Individuals who participated in one program gained experience to be leaders or intellectual resources in following programs.

But two things have coalesced in recent years to complicate such transfers of knowledge: Defense budgets have become constrained, and the operational lives of submarines have lengthened as the vessels' production and maintenance procedures have benefited from continuous process improvements and as navies have changed how they operate the vessels. The result is that the pace at which submarines will be replaced is likely to slow, creating significant time gaps between successive programs and far fewer opportunities for veteran personnel to pass

on their knowledge to succeeding generations of submarine workers and program managers.[1]

Recognizing the importance of documenting and imparting experiences from past submarine programs, the Head, Maritime Systems Division, in Australia's Defence Materiel Organisation asked the RAND Corporation to develop a set of lessons learned from the *Collins* submarine program that could help inform future program managers.

The *Collins* was the first submarine built in Australia. As with any complex endeavour undertaken for the first time, there were numerous bumps along the road to the delivery of the *Collins*-class submarines, and challenges remain today in keeping the *Collins* boats operationally ready. There were also several success stories. Thus, the *Collins* program is fertile ground for important lessons in the conduct of a new submarine program.

The RAND project team derived lessons by drawing from *The Collins-Class Submarine Story: Steel, Spies, and Spin*, the definitive history of the *Collins* program written by Peter Yule and Derek Woolner,[2] and from a wide range of literature on the *Collins* program and other submarine design and construction programs. The team supplemented this literature review with interviews with more than 25 of the key Australians and Americans involved in the program.[3]

RAND's search for lessons also involved reviewing the history of Australia's submarine fleet from its genesis in the months leading up to World War I through the *Collins* program; investigating how operational requirements were set for the *Collins* class; exploring the acquisition, contracting, design, and build processes that the *Collins*

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[1] There are exceptions, of course. For example, China and India have vigorous design and build programs and Germany and France have new designs or modifications of existing designs every six to eight years to support their export markets.

[2] Peter Yule and Derek Woolner, *The Collins Class Submarine Story: Steel, Spies and Spin*, Cambridge, UK: Cambridge University Press, 2008.

[3] The Swedish firm Kockums was the primary design organization and was a key part of the consortium that built the submarines. The consortium, called the Australian Submarine Corporation (ASC), had Australian designers and engineers joining Kockums personnel with additional experienced designers and builders from the United States and the United Kingdom.

program employed; and assessing the plans and activities surrounding integrated logistics support (ILS) for the submarine class.

RAND focused on identifying managerial lessons. The project team looked for instructive aspects of how the *Collins* program was managed, issues that impacted management decisions, and the outcomes of those decisions. At times, it was difficult for the team to judge the success or the failure of program decisions. Views change during the conduct of a program and are based on the perspective of individuals. The important point is that decisions were not necessarily "good" or "bad." Rather, they were or were not fully informed by knowledge of the risks and consequences. Since cost is typically the metric for judging program success, the majority of the lessons focus on controlling program costs.

Australia's First Submarine Program

In the 1970s, the Royal Australian Navy (RAN) began planning to replace its *Oberon* class of submarines, the first of which was slated to retire from service in the early 1990s. Australia's submarine force had been fulfilling a number of roles—maritime surveillance, maritime strike and interdiction, reconnaissance and intelligence collection, Special Forces operations and protection of vital sea lanes—and the RAN wanted the replacement vessels, known as the *Collins* class, to be more capable in these roles than the *Oberon* fleet.

Australia intended to take an evolutionary approach in procuring the *Collins* class. Its initial request for tenders specified that the submarine employ a design already in service or would be in service by 1986. This approach was thought to mitigate the inherent risk in the country's first attempt at constructing this new class of submarines domestically. Design risks remained, however, because most conventional submarines then available that could serve as a basis for the

Collins were designed for short-duration operations in the colder waters of the Baltic Sea.[4]

Because those submarines' operating capabilities and environments differed greatly from the *Collins'* expected performance and operating conditions, the *Collins* program ended up pursuing a developmental platform and a developmental combat system.[5] This introduced a high degree of risk into the program, which had no risk management mechanisms. While an off-the-shelf design would not have met Australia's unique operational requirements, it would have been less risky to build.

During *Collins'* build phase, the ASC shipbuilding consortium that oversaw the program suffered business, contract, and legal problems. The main issue involved Kockums as the subcontracted designer and part owner of ASC. In the 1998–2000 period after the delivery of the first of the *Collins*-class boats, Kockums lost much capability and was sold to the German firm Howaldtswerke-Deutsche Werft (HDW).

Despite these and other difficulties, the *Collins* class is often heralded as one of the most impressive diesel submarines in the world today. The *Collins* has one of the most strenuous concept of operations (CONOPS) of all diesel submarines, and overcoming all of the obstacles the program faced was not easy. Australia had never built a submarine, maintained a class, or transitioned platforms on its own,

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4 Kockums' experience in designing boats for Baltic operations gave it an approach to submarine design that was not always consistent with the Australian CONOPS. There were large differences in the endurance requirement and operating environments for the Swedish and Australian submarine force. The Swedes ran their submarines for a week at a time, departing on Monday and returning to port on Friday. Thus, their subs were typically smaller with a lower usage rate and power requirements. The Australians, on the other hand, transited greater distances and were on station for months at a time, which had a number of implications for fuel storage, hotel services, and other hull design features. Additionally, Kockums was accustomed to designing for operations in the Baltic, where the water is cold and relatively calm, which was problematic for Australia's salty, open-ocean environments and tropical waters.

5 The *Collins* was the first class of submarines constructed in Australia. While the RAN had experience with maintaining the *Oberon* class and had previously built commercial ships and some naval vessels, Australia's submarine construction capability had to be built from the ground up.

and its experience in successfully doing so offers many lessons to future programs.

Lessons in Supporting and Managing the Program

Successful programs are well managed and broadly supported. Effective management and support must last throughout the life of the program, from concept to disposal. Important lessons here include the following:

- *Ensure that the program is adequately supported by the navy, the government, the scientific community, and the public.* Support must be both external to the program and internal within the navy and submarine community.[6] Political support is most important for the advancement of a new acquisition program.
- *Ensure that the program is open and transparent*. Full disclosure throughout the program is necessary to obtain government, industry, and public support. In this regard, a good media management program is necessary. Bad press greatly and negatively affects the program. Effective communications must be proactive, not reactive, in briefing the press, academia, and state governments.[7]
- *Involve appropriate organizations, commands, and personnel from the beginning.* The program and the procurement agency must be informed customers supported by adequate technical, operational, and management expertise.[8]

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[6] Both the non-submarine portion as well as the submarine force of the RAN was not adequately supportive during the early stages of the *Collins* program. Adequate support includes continuity in managing the program at various levels. During the *Collins* program, the head of procurement, the project office management, and the chief executive officer of the prime contractor were all replaced at one time or another.

[7] One lesson from the *Collins* program is the need to effectively manage the media. The bad press that accompanied the *Collins* effort still taints the program in the mind of the general public.

[8] One criticism of the Collins program concerns the absence of the technical community during the early stages of the program. Specifically, there was a lack of close coordination between various defense interests. Some critics mentioned that the role of the Defence Sci-

- *Involve experienced people in key management positions.* This requires a strategy to grow people so they are experienced in various disciplines. This top-level, strategic lesson must be implemented far in advance of any specific program. This goes for other programs beyond just submarines.
- *Take a long-term strategic view of the force and the industrial base.* The technical community and the industrial base that designs, builds, and maintains the fleet must be sustained so they can provide the required capabilities when needed. A key lesson is that a new submarine development program produces more than a strategic military asset; it also contributes to domestic economic goals and is one part of a long-range operational and industrial base strategy.

Lessons in Setting Operational Requirements

Decisions made early regarding the desired operational performance of the new submarine influence the program's technology risk and its likelihood of success. The platform's operational requirements are translated to performance specifications that lead to technology choices to achieve the desired performance. The operational requirements, especially the desired operational availability, also impact ILS planning. Important lessons here include the following:

- *Understand current technology as it applies to the program.* Program managers must be supported by a technical community that completely understands the technologies that are important to the program, where they exist, and which ones must be significantly advanced. Relying too heavily on significant advances in

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ence and Technology Organisation (DSTO) had not been sufficiently defined at the outset. Another problem was the lack of co-location of the appropriate organizations during the program.

technology will lead to risks in achieving the desired operational capabilities.[9]

- *Understand how a platform's operational requirements impact technologies, risks, and costs.* Desired operational performance will drive the characteristics of the platform and the technologies needed to achieve the performance goals. Program managers not only need to know the current state of various technologies but also to understand how changes to operational requirements relate to the technology levels that are available. This relates to recognizing trade-offs between operational requirements and technological risks (and associated cost and schedule implications).[10]
- *Understand that operational requirements must also specify how to test for the achievement of that requirement.* Although it is often difficult to plan tests early in a program, doing so is necessary to ensure that all parties agree on the processes for measuring how the performance of the platform meets operational capability objectives. Incremental testing of equipment before it becomes part of a system and before that system is inserted into the hull should be encouraged.

Lessons in Establishing an Acquisition and Contracting Environment

Establishing an open and fair acquisition and contract environment and understanding the risks involved with desired operational capabilities are two important aspects of any program. Good decisions here—

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[9] The *Collins* program began with a desire to base the design on an existing submarine or one that would soon be in service with another country's navy. Unfortunately, neither Kockums nor the RAN fully appreciated the difference between the operational requirements of the *Collins* and the capabilities of existing conventional submarines. The end result was a new submarine design that pushed technology limits, especially in the case of the combat system. The program did not readily understand or plan for the risks that were involved in such a radical new design effort.

[10] The developmental platform and the developmental combat system in the *Collins* led to a high degree of risk. Backing off requirements slightly, especially with the combat system, could have significantly reduced those risks.

concerning the organizations to be involved in designing and building the new submarine, the type of contract, the specifics within the contract (including incentives), the decisionmaking process to employ when issues arise, and the payment schedule—will resonate throughout the life of the program. Key lessons for establishing an effective acquisition and contracting environment include the following:

- *Establish a collegial and interactive environment with the industrial base organizations.* This includes correctly structuring contracts, sharing risks where appropriate, developing long-term relationships, and developing and supporting equipment suppliers. These points are amplified below.
- *Structure contracts with provisions to handle program risks.* Although the government can try to place all risk on a contractor through use of a fixed-price contract, the government itself ultimately holds all program risk. It is far better to structure a contract that holds the contractor responsible for risks under its control (labor rates, productivity, materiel costs, etc.) and holds the government responsible for risks beyond the contractor's control (inflation, changing requirements, changes in law, etc.).[11]
- *Define contractor roles and responsibilities, especially between prime and subcontractors.* It is important to do this early. When cooperation between contractors is essential to the success of a program, the government must actively manage their interactions and/or appropriately incentivize them to cooperate.[12]

[11] The fixed-price contract used for the *Collins* program had poorly defined specifications. ASC had no motivation to provide more than what it interpreted as its obligations, and the Commonwealth took the position that it would pay no more than the original contract price and was afraid to enforce the specifications for fear of being liable for a contract change it could not pay for.

[12] The undefined relationship between ASC, the platform prime, and Rockwell, the combat system prime, plagued the *Collins* program. The Commonwealth negotiated the contract with Rockwell, yet it made ASC the prime contractor responsible for the successful delivery of the combat system. When the problems with the development of the combat system emerged, ASC wanted to hold Rockwell in default but was prohibited from taking that step by the Commonwealth.

- *Specify desired performance requirements and how to test that they are achieved.* The Commonwealth should state the desired performance capabilities of the platform but should not specify how those performance requirements will be achieved unless a significant benefit or risk is being managed. The prime contractor should have the ability to decide how best to meet performance requirements. The Commonwealth should establish an independent evaluation of the requirements and perform a thorough cost trade-off analysis to understand how the desired requirements affect costs and how modified requirements may lead to reduced costs. The contract should also outline how to test that the design meets those requirements.[13]
- *Develop a timely and thorough decisionmaking process.* Issues will arise during the conduct of the program, and it is important that a decisionmaking process is in place that involves all applicable organizations—the RAN, the technical community, the program office, and the contractor.
- *Establish an agreed-upon tracking mechanism and payment schedule.*[14] It is important to have an effective system for tracking progress and a payment schedule that is tied to clearly defined milestones and that reserves adequate funds to handle difficulties that occur later in the program.
- *Develop a process to manage changes*. Changes will invariably occur. They may crop up in the desired performance of the platform; in the systems and equipment used to achieve performance; in the schedule; or in the responsibilities of the organizations involved in designing, building, and testing the platform. Changes may impact cost, schedule, or capability. Management structures must be in place to deal with any contract changes that are proposed during the program.

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13 Unfortunately, adequate testing procedures were not developed or enforced for the *Collins* program. For example, comprehensive tank testing of the hull design was not specified or accomplished, and the Hedemora engine configuration installed on *Collins* was not fully tested before the submarines went to sea.

14 The *Collins* program paid the contractor the majority of funds well before the project was complete. This led to little or no funds being available to handle problems that arose later.

- *Include an adequate contingency pool.* A complex project normally has a contingency fund on the order of 10 to 15 percent or more. However, the *Collins* contract's contingency fund was approximately 2.5 percent.

Lessons in Designing and Building the Submarine

It is important to get all the right organizations—designers, builders, operators, maintainers, and the technical community—involved throughout a program, in order to understand how operational requirements impact design and construction and to plan for the appropriate testing of the systems and platform to ensure requirements are met. Lessons for the design and build process overlap to some degree with the lessons that emerged from the earlier stages of the program. These design and build lessons include the following:

- *Involve builders, maintainers, operators, and the technical community in the design process.* It is important to think of the design team as a collaboration of submarine draftsmen and design engineers with inputs from those who must build to the design, operate the submarine, and maintain it. This collaboration should extend throughout the duration of the design program.[15]
- *Choose a design organization that knows the operating environment.* The design organization needs to appreciate the demands of the concept of operations and the operating environment. Different operating environments require different equipment and different procedures for operating it.
- *Listen to technical community concerns about risk.* The degree to which existing technology is "pushed" in a new design will impact the risks to cost, schedule, and performance of the end platform. The technical community, supplemented by outside expertise from industry and allied technology partners as necessary, should

[15] However, throughout the design/build process, it is important to keep in mind that the cost effectiveness of the submarine's post-delivery or ILS period is the true design and construction target.

understand the state of technology and the degree to which a new design extends that technology.[16]

- *Develop realistic design cost estimates.* Programs must fully understand the likely costs to design and build the end product and be able to incorporate important modifications.
- *Design for removal and replacement of equipment.* Adequate access paths and removal hatches should be included in the design, so as to facilitate removing and replacing damaged or obsolete equipment. For command, control, communications, computing, and intelligence (C4I) equipment, modularity and interoperability should be incorporated into the design.
- *Consider potential problems with foreign suppliers.* If foreign suppliers are chosen for key equipment in a new program, there should be assurances that they are economically viable and will remain so during the operational life of the submarines.[17]
- *Specify and manage adequate design margins.* Without adequate margins, it may not be possible to modernize and upgrade equipment.
- *Complete the majority of the design drawings before construction begins.* It is far better to delay construction to ensure the design is largely complete rather than risk the costly rework and changes typically resulting from an immature design. A good rule of thumb is to have 3D CAD electronic product models approximately 80 percent or more complete when construction begins.[18]
- *Develop a thorough and adequate testing program.* A test procedure that ensures requirements have been met should be developed during the design and build portion of a new program.

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[16] The combat system for the *Collins* is an example of reaching too far from a technology perspective, with less than satisfying results.

[17] The *Collins'* electric generators, designed by a French company, are a prime example of these problems. That company's Australian partner lacked the knowledge or specialty manufacturing equipment or systems required to build them. The Hedemora engines are another example of a foreign supplier not being able to adequately address problems that cropped up.

[18] Only 10 percent of *Collins* drawings were completed when construction commenced.

- *Obtain intellectual property rights.* Programs need to have the intellectual property rights to the design of the basic platform and fitted equipment.[19]

Lessons in Establishing an Integrated Logistics Support Plan

Operating and supporting new submarines after they enter service account for the vast majority of their total ownership costs. Therefore, it is imperative to establish an ILS plan for the new submarines. A more exhaustive lessons-learned study should be conducted based on the ongoing experience with supporting the *Collins* class. Important lessons here include the following:

- *Establish a strategic plan for ILS during the design phase.* Such a plan must be put in place early in the program. Personnel from organizations responsible for maintaining the submarine should be involved in the design process.
- *Specify the concept of operations and maintenance of the submarine.* The operational concepts must recognize that the submarine will require time for preventive and corrective maintenance and for equipment modernizations. The end result should be a periodic cycle of training, operations, and maintenance that holds throughout the life of the submarine.
- *Consider equipment reliability and plan for preventive and corrective maintenance.* To develop a maintenance plan, issues connected with equipment reliability and hull corrosion and fatigue must be well understood. This involves frequent interactions with the design authorities and the original equipment manufacturers (OEMs) to obtain the needed data and information. If needed,

[19] Without such intellectual property rights, Australian design efforts on the submarine class to replace the *Collins* may be constrained. Although Kockums and the Department of Defence reached a settlement in 2004 that gave ASC and its subcontractors access to Kockums' intellectual property, Kockums' proprietary information remained protected so that no intellectual property from the *Collins* could be used in a new Australian submarine design.

fund an effort to develop better maintenance planning taking into account the current infrastructure.

- *Determine the "when, where, and who" for maintenance, modernization, and training.* The strategic ILS plan should include when various maintenance, modernization, and training will be performed; where the activities will take place; and which organizations will perform those activities.
- *Plan for equipment modernization.* Equipment on the submarine, especially electronics, will need updating, and future equipment modernizations must be part of the strategic ILS plan. Modernizations may involve the higher-level maintenance organization but will more likely involve the OEMs.
- *Consider ILS from a navy-wide rather than program perspective.* Program managers must recognize that there will be demands on maintenance and training resources from other submarines as well as RAN surface ships. This is especially important for limited maintenance facilities, such as the drydocks that are used across several ship classes.
- *Establish a planning yard function and develop a maintenance and reliability database.* A planning yard function to track maintenance and establish future workloads is important to ensure that the right maintenance is done at the right times.
- *Plan for crew training and transition of the fleet.* The ILS plan should include the "when, where, and who" for training activities, as well as a plan for transitioning crew members from the old class to the new class.
- *Maintain adequate funding to develop and execute the ILS plan*. In order to develop a thorough ILS plan, adequate funding must be available and protected during the conduct of the program.

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Of course, any errors of omission or commission in the document are the sole responsibility of the authors.

Abbreviations

Ada	a high-level computer programming language, extended from Pascal and other languages
AMS	Australian Maritime Systems
ANAO	Australian National Audit Office
ANZUS	Australia, New Zealand, United States Security Treaty
ASC	Australian Submarine Corporation (now ASC Pty Ltd)
ASR	Admiralty Standard Range
C4I	command, control, communications, computing, and intelligence
CONOPS	concept of operations
CSA	Computer Sciences of Australia
DMO	Defence Materiel Organisation
DOR	detailed operational requirement
DSTO	Defence Science and Technology Organisation
FCD	full cycle docking
ILS	integrated logistics support
IP	intellectual property
OEM	original equipment manufacturer

RAN	Royal Australian Navy
RFT	request for tender

CHAPTER ONE

Introduction

Lessons from past experiences are an important tool for preparing managers to conduct future programs successfully. This is especially true for the management of complex military programs governed by various rules, regulations, procedures, and relationships not typically found in commercial projects. In the past, frequent new programs would afford the opportunity for junior-level managers to gain experience, preparing them for more senior management roles in future programs. However, the longer operational lives of current naval platforms and the pressures of constrained defense budgets have resulted in longer gaps between the start of new programs in many countries. The managers of new programs often do not have the benefits of experiences gained on previous programs. In this environment, it is important that lessons from previous programs, both good and bad, be captured and provided to future program managers.

Recognizing the need to document the lessons from past programs to provide insights for future program managers, the submarine organizations of the United States, the United Kingdom, and Australia asked the RAND Corporation to codify the lessons from past submarine design and acquisition programs. This volume presents the lessons learned from Australia's *Collins* submarine program.

The *Collins* was the first submarine built in Australia. The Swedish firm Kockums was the primary design organization and was a key part of the consortium that built the *Collins*-class submarines. The consortium, the Australian Submarine Corporation (ASC), joined together Australian designers and engineers, Kockums personnel, and additional experienced designers and builders from the United States and the United Kingdom. As with any complex endeavour undertaken for the first time, there were numerous bumps along the road to the delivery of the *Collins*-class submarines, and challenges remain today in keeping the *Collins* boats operationally ready. There were also several success stories. Thus, the *Collins* program is fertile ground for important lessons in the conduct of a new submarine program. The lessons from the *Collins* should help the managers of the Future Submarine program, the replacement for the *Collins*, avoid some of the problems that the *Collins* program experienced and take advantage of the successes of that program.

Organization of the Monograph

Chapter Two presents a brief history of submarines in Australia and provides a background for the start of the *Collins* program. Chapter Three discusses how the operational requirements for the *Collins* were set, and Chapter Four describes the acquisition and contracting process used for the *Collins* program. Chapter Five explores the design and build of the *Collins* submarines, the problems in developing an integrated logistics support (ILS) program for the *Collins*, and lists several of the successes of the program. Chapter Six provides the lessons from the *Collins* program.

CHAPTER TWO

History of Australia's Submarine Fleet

The genesis of the Australian submarine fleet was in May 1914, two months before the onset of World War I, when two British-built submarines—the AE1 and the AE2—were delivered to Australian authorities in Sydney by the Royal Navy. Later that year, the AE1 was part of an Australian Naval and Military Expeditionary Force sent to seize and destroy German wireless stations in New Guinea; it never returned from a patrol out of Rabaul.

The AE2 met a similar fate in the Gallipoli Campaign. In April 1915, the AE2 successfully penetrated the narrows in the Dardanelles Strait and attacked Ottoman ships in the Sea of Marmara but was subsequently hit by Turkish gunfire.

Thus, within a year of delivery of its first submarines, Australia found itself without a submarine fleet. Talks soon began about finding replacements for the two submarines. Jans Jensen, assistant minister representing the Minister for Defence in the House of Representatives, said that he hoped soon to have more than two submarines in Australia but at the time the country lacked the capability to build them.

In 1919, Australia accepted six surplus "J" class submarines from Britain, which arrived in bad shape and required extensive refits. The Cockatoo Island Dockyard in Sydney had many months' notice of the arrival of the six subs but was unprepared for the refits. Additionally, the Royal Australian Navy's (RAN's) budget had been slashed because of postwar hopes of disarmament and a stagnant economy. Thus, the six boats were laid up in 1921 and sold for scrap the following year.[1]

To regain its lost submarine capability, the Australian government in 1924 agreed to purchase the *Oxley* and *Otway* from the Royal Navy (UK). But bad luck struck the Australian submarine fleet again: The submarines were not ready for service until 1929 and were returned to the Royal Navy two years later. Lengthy delays and mechanical failure caused both the Australian public and the RAN to turn against the programs.

Australia did not regain its submarine capability for several decades. Although the Australian shipbuilding industry expanded and built more than 100 naval vessels between 1939 and 1946, Australia had no submarine fleet during World War II. However, numerous Australian sailors served with the Royal Navy submarine fleet, and a large number of U.S. submarines operating in the Pacific theater were based in Western Australia during the war. After the war, Australian naval authorities had no interest in maintaining a submarine fleet, but in 1949 the Royal Navy arranged to have its fourth submarine flotilla based in Sydney. This enabled the dockyard at Cockatoo Island to develop submarine refit and maintenance skills.

In 1963, Australia's Minister of the Navy, John Gorton, announced cabinet approval to acquire four *Oberon* submarines from Britain. At this point, Australia had never built a submarine, and there were questions as to why some of the *Oberons* could not be built in Australia. Although many people—including the Chairman of the Australian Shipbuilding Board, H. P. Weymouth, and the managing director of Cockatoo, Captain R. G. Parker—believed that it was possible and should be done in Australia, it was decided that building in Australia would be too costly. Thus, four *Oberons* were built in Britain and delivered by 1970. Two more were ordered in 1971 and delivered in 1977 and 1978.

These submarines proved particularly adept at conducting long-range surveillance missions during the Cold War and operating for long periods without support from land bases. Australian submarine

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1 Yule and Woolner, 2008.

operations helped augment U.S. Navy operations in the Pacific during the Cold War and provided useful intelligence information.

Although the *Oberons* were built in Britain, their refits were conducted at the Cockatoo Island Dockyard. The RAN depended on overseas suppliers for 85–90 percent of the support for the *Oberon*-class subs, and the refits (which took place every five years) cost up to 76 percent of the vessels' original purchase price.[2] Due to the number of problems with refits, Australia began to once again consider developing an organic capacity to construct submarines to replace the *Oberons* as they began to decommission in the 1990s.[3]

It is important to recognize that throughout the operation of the *Oberon* class, Australia had always relied on the United Kingdom for its submarines, maintenance, spare parts, and training. In effect, the RAN was not the "parent navy" for the submarines; that role was filled by the Royal Navy. The lack of RAN experience as a parent navy for a submarine fleet played a big role in the *Collins* program, especially in supporting the boats once they entered service.

Collins Background

Between 1945 and 1974, the Australian economy grew at a constant pace. However, as the last *Oberons* were delivered in the late 1970s, the global oil crisis and rapid wage-inflation caused unemployment to climb above 10 percent, spurred large budget deficits, and brought on the worst recession since the mid-1930s. Australia's protectionist polices had reduced its industrial competitiveness, and many in government called for a more open and innovative industrial sector. During this time, due in part to budgetary pressures, the Labour government, led by Prime Minster Robert Hawke, cancelled the RAN's aircraft carrier replacement program. This cancellation led to a maritime capability vacuum.

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2 Woolner, 2001b.

3 Kelton, 2005.

Some policymakers recognized that a new class of submarines could fill this vacuum and advocated constructing the boats in Australia on the basis that it would create jobs, benefit technology transfer, modernize the defense industry, and improve industrial relations practices.[4] Although building a submarine construction capability from the ground up was projected to be costly, manufacturing a new class of submarines domestically was seen as more cost-effective in the long run, as the local knowledge base would be established for refits and maintenance.

In 1978, the Director of Submarine Policy presented a brief on the necessity of an *Oberon* replacement plan. One of his suggestions was that the construction of the new class in Australia should be considered. A year later, the Cockatoo Island Dockyard began a three-year study to look into the feasibility of building modern submarines in Australia. It concluded that building submarines in Australia was "entirely practical" and would yield future benefits in support and maintenance.[5] From the beginning, there was significant industry support for an all-Australian submarine construction program.

Although the build of the new submarines was supported by industry and members of the government, there was not general support within the RAN for new submarines, whether built in Australia or purchased from another country. Because the RAN was relatively small, it had to make the most of limited funding, and many in the RAN did not want new submarines to compete with surface combatants for the limited funding.[6]

However, there was significant political support for the new submarine, led by Minister of Defense Kim Beazley. The government approved the first phase of the new submarine acquisition in the 1981–82 budget, and project definition studies began in January 1982. The *Collins* class was officially established on February 20, 1982, as

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[4] Yule and Woolner, 2008.

[5] Yule and Woolner, 2008.

[6] Within the RAN, submariners made up a relatively small component of the officer corps, and their career paths were limited. Thus, senior leadership primarily came from the surface fleet.

Project 1114–New Submarines.[7] The new project submarine office was set up that same month. Its staff included experienced submarine officers, engineers, and naval architects.

In its first year, the project team considered purchasing a nuclear submarine from the United States, United Kingdom, or France. The United States was unwilling to sell its nuclear technology, and the United Kingdom was unable to do so because of its commitments to the United States.

France, however, was willing to sell *Rubis*-class submarines. Estimated to cost about 1.7 times the cost of a French conventional submarine, the *Rubis* submarine was perceived by Australian authorities to have several drawbacks, the most important of which was that Australia would have to rely on France for maintenance and support and would therefore be involved in a situation similar to its unpopular dependence on Britain with the *Oberons*. In addition, the costs of overhauling and refueling a nuclear submarine would be very high. Also, developing the infrastructure necessary to support a nuclear ship would be extremely expensive given existing budget limitations. The Australians decided not to pursue the nuclear submarine option due to the cost of infrastructure and support and to political sensitivities concerning nuclear power.

The project office determined that the best path forward was to buy an existing diesel submarine design and build the submarines in Australia. The following chapter describes how the requirements were determined for this new class of submarines.

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[7] Kelton, 2005.

CHAPTER THREE

Setting the Requirements: Evolutionary Versus Revolutionary Approach

This chapter describes how the operational requirements for the *Collins* class were set early in the program. Establishing the desired capabilities for a platform greatly impacts the technological risk involved in the program and affects the program's overall conduct.

The Australian submarine force fulfils a number of roles—maritime surveillance, maritime strike and interdiction, reconnaissance and intelligence collection, special forces operations, and protection of vital sea lanes. The RAN wanted the new class of submarines to be more capable in these roles than its existing fleet of *Oberons*, which were expected to begin retiring from service in the early 1990s. Also, in the early 1980s, the United States sought Australia's assistance through the Australia, New Zealand, United States Security Treaty (ANZUS) to ensure that the Pacific remained open in the face of the "Soviet challenge."[1] Thus, the desire for covert surveillance from the North Pacific Ocean also drove the required design, range, endurance, speed and weapon load parameters for the *Collins* class.[2]

Australia wanted to increase its undersea capability for various reasons. First, it desired to maintain an ability to provide a long-term presence in the littoral of a potential aggressor. Additionally, the ability to gather intelligence at considerable distances from Australia was

1 ANZUS was signed in 1951 to protect the security of the Pacific. This alliance was a result of the direct threat of attack on Australia and New Zealand during the course of World War II. Although the United States suspended its treaty obligations toward New Zealand in 1986, Australia and the United States continue to honor ANZUS.

2 Kelton, 2005.

crucial. The submarine force also offered invaluable trade protection, inasmuch as 90 percent of Australia's trade was conducted via shipping. According to former Royal Australian Navy Commander and *Collins* planning manager Andrew Millar, the *Collins*' range should extend from the far North Pacific to the Persian Gulf to meet Australia's unique strategic circumstances.[3]

The performance requirements for the new submarine were largely determined by the RAN; for the most part, the specifications went unchallenged. Detailed operational requirements documents (DORs) were never officially produced prior to the start of the project. DOR Part 1 was introduced retrospectively but never endorsed; DOR Part 2 was produced and endorsed in 1999.[4]

The accepted performance specifications for the new submarine by the RAN included an increased transit speed (25–30 percent faster), a superior indiscretion rate,[5] increased submerged endurance, and a smaller crew (41 persons) than the *Oberon*.[6] Open-ocean operation required high endurance and low indiscretion rates, which in turn required a larger hull size to provide more volume for fuel and batteries.

The RAN lacked procedures and insights to understand the implications of the ambitious requirements for the costs of the platform and the technologies needed to achieve the performance goals. Furthermore, there was no established feedback mechanism through which industry could weigh in on the effect of requirements and specifications on the final design and functionality of both the platform and the combat systems. Finally, there was little involvement by the operators in the concept development and early design phase. As the program progressed, the operators began to weigh in with requirement changes, but at that point it was difficult to change any of the specifications.

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[3] Kelton, 2005.

[4] Australian National Audit Office (ANAO), 2002.

[5] The *indiscretion rate* or *indiscretion ratio* is the percentage of time during an operational mission that the snorkel is raised to draw air (called "snorting") to run the diesel generators when recharging the batteries. A raised snorkel increases the probability that the submarine will be detected.

[6] Woolner, 2001b.

During the 1970s, the Submarine Warfare Systems Centre designed and integrated a number of successful upgrades to the *Oberon* weapons system. "The weapons system upgrade program made the *Oberons* probably the most capable conventional submarines in the world and it gave the people who had worked on it enormous confidence in their ability to tackle complex projects successfully."[7] However, developing the requirements for a new combat system is very different from making marginal upgrades to an existing system. Although the desired characteristics of the new system were known, what was lacking was the expertise to fully understand what was practical and achievable.

The high level of confidence, combined with rapid improvements in information technology in the 1980s, influenced the RAN's requirements for a fully integrated combat data system using a distributed data bus instead of the centralized mainframe computer that was the basis for naval combat data systems at the time. The RAN specified that the new combat system should be able to "assimilate and correlate up to 1,000 contacts simultaneously, and reduce them to the six most threatening contacts."[8] It also specified the use of the ADA programming language. The combat system was expected to be flexible enough that an operator could perform any function at any console at any time. These early decisions to specify a combat system solution rather than defining a performance requirement and allowing industry to develop the preferred solution would lead to major problems during construction of the submarines.

Australia initially intended to take an evolutionary approach to the procurement of the *Collins* class. Its initial request for design tenders specified that the design should be currently in service or would be in service by 1986, but that it also could be upgraded to Australia's unique requirements. This approach was seen as mitigating the risk inherent in the country's first attempt at indigenous construction of a new class of submarines. However, the majority of the conventional submarines that could serve as a basis for the *Collins* were designed for

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7 Yule and Woolner, 2008, p. 25.

8 Yule and Woolner, 2008, p. 36.

short-duration operations in the colder waters of the Baltic Sea. Thus, the design parameters and operating conditions of existing conventional submarines differed greatly from the expectations and operating conditions for the *Collins*.

The *Collins* program involved building both a developmental platform and a developmental combat system. These parallel developments inserted a high degree of risk into the program when no mechanisms were in place to properly manage the risk. While an off-the-shelf design may not have met Australia's unique operational requirements, it would have been less risky to build. Significantly scaling up an existing design is difficult at best and typically leads to a whole new design, especially for propulsion and distributive systems (electrical; heating, ventilating, and air conditioning; etc.) that run throughout the submarine.

Evolutionary or revolutionary technologies under consideration should be reviewed and discussed with all stakeholders, including designers, operators, project managers, and technical personnel in government organizations and industry. Furthermore, decisions on desired capabilities should be informed by a thorough understanding of the technologies that are currently available and the relationship between pushing those technologies and the cost and schedule of the project. Unfortunately, requirements decisions were made without inputs from the whole community and without an understanding of the risks and implications of technology decisions.

Technologies that advance the current state of the art should also be adequately prototyped and tested prior to being incorporated into a new design. This prototyping and testing was not always followed during the *Collins* requirements process. For example, type-testing was not done to the extent that it should have been for the Hedemora engines on the *Collins* class. At the time the subcontract was awarded to Hedemora for the development of an 18-cylinder engine, Hedemora was producing 12-cylinder engines for Sweden that had been tested in an operational environment. These tests on the 12-cylinder engine were the basis for accepting the subcontract, but Hedemora had never produced an 18-cylinder engine.

In hindsight, the technology for integrating the combat system was not sufficiently developed to be viable for the *Collins* class; the necessary computing power and system architecture were not available until ten years later. In addition, the resulting combat system design was unnecessarily integrated. The resulting design was extremely complex and nearly impossible to develop.

The next chapter describes how the operational requirements were incorporated into an acquisition and contracting strategy.

CHAPTER FOUR

Contracting and Acquisition Strategy

When Australia started its search for a submarine designer in the 1980s, only nine companies worldwide designed and built diesel submarines. Seven of them were invited to provide proposals for the *Collins* project definition studies.[1]

The initial request for tender (RFT) specified that the selected design should be one that was then in service or would be in service by 1986. The purpose of this was to reduce the project risk. Respondents to the tender were also expected to have some experience building a submarine in the host nation and were asked to explain how they would promote Australian industry with the project. All seven invited companies provided proposals, as outlined in Table 4.1.

The Italian proposal was quickly discarded because it failed to consider production in Australia. The French design could not handle the RAN's American weapons. Its noise performance was not much better than the *Oberon,* and its electrical power and spares were not as big as desired. Thus, it was deemed unsatisfactory. The Dutch proposal had only 75 percent of the battery endurance, four out of the six required torpedo tubes, and other characteristics that the RAN deemed unsatisfactory. Vickers' design had only 60 percent of the required range and endurance, and the RAN deemed both the A and B designs to be inefficient. Thyssen's design was noisy and was the company's first design, so it was also discarded.

1 Woolner, 2001b.

Table 4.1
Countries and Companies Providing Proposals to Design the *Collins* Class

Country	Company	Proposed Vessel/Design
Italy	Cantieri Navali Riutini	Enlarged version of the *Sauro*, design of the early 1970s
France	Charles Dubigeon	Conventionally powered version of the nuclear-powered *Rubis*
Netherlands	United Shipbuilder Bureaux and P Roterdansche Droogdok Maatchappig	*Walrus* (Adapted USS *Barbel*)
United Kingdom	Vickers	Type 2400 (A & B) *Upholder*
Germany	IKL & HDW	IKL Type 2000 design
	Thyssen	Type TR1700
Sweden	Kockums	Type 471 (enlarged A17)

Four contractors were selected for the funded development study phase.

- Australian Maritime Systems (AMS)—a joint venture of Eglo Engineering in Australia and IKL/HDW in Germany
- Australian Submarine Corporation (ASC)—a consortium established to build the Swedish design, which had as its original stockholders Kockums (30 percent), Chicago Bridge and Iron (20 percent), Wormald (25 percent), and Australian Industry Development Corporation, a government-owned merchant bank (25 percent)
- Rockwell in the United States
- Signaal in the Netherlands.

AMS and ASC were awarded contracts to further develop the submarine platform design. Rockwell and Signaal were awarded contracts to further develop the combat system.

The tenders from the four competitors were submitted in late 1986. Each design had advantages and disadvantages. An extensive evaluation of these tenders concluded that the Swedish submarine design was superior to the German design, and Kockums/ASC was awarded the contract in May 1987. Kockums' experience with designing and building submarines for the Swedish Navy, its data on reliability, and its technology with modular build were all in its favor. Rockwell's combat system concept and preliminary design were preferable to Signaal's approach. Although Kockums and Rockwell were the favored bidders, negotiations were held with all four to maintain competition.

Unfortunately, according to Yule and Woolner,

> The definition study failed to produce its central outcome, a set of firm performance and production details that could easily be turned into contractual form. The proposals were considered to be at the preliminary design stage and "requiring substantial development before a build specification could be prepared."[2]

However, political pressures rushed the *Collins* acquisition process because the government wanted to have an agreement in place before the upcoming election. The head of the Australian negotiating team was instructed to negotiate a fixed-price, performance-based commercial contract.[3]

When the contract was awarded, ASC was "little more than a name and a letterhead."[4] ASC quickly needed to assemble its workforce, and a major recruiting program began for staff at all levels. A large number of engineers and other professionals joined ASC in 1987. The first chief executive started work in 1988, and ASC started to employ

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2 Yule and Woolner, 2008, p. 109.

3 In these circumstances, the final agreement contracted with ASC had a directed subcontract (negotiated by the government) with Rockwell, but left several items unresolved. A number of items, including ILS, were provisionally priced, requiring further negotiations to settle work scope and price. Moreover, insurance responsibilities remained unsettled and procedures for pricing changes to the specifications were still unresolved.

4 Yule and Woolner, 2008, p. 121.

people with production expertise. ASC needed to create hundreds of subcontracts, of which at least 70 percent had to be spent in Australia.

The government relied on a fixed-price contract for the *Collins* project after incurring significant cost overruns on preceding acquisition projects that had used cost-plus contracts. Officials in defense and government felt that a fixed-price contract would transfer most risk to the contractor. However, this acquisition strategy was not flexible enough to accommodate what turned out to be a developmental program. In particular, the contract led to inadequate allocation for contingencies. Whereas normal complex engineering contracts generally have a contingency between 10 percent and 15 percent, the contract with ASC had only a 2.5 percent contingency. This low contingency level would hamper the ability to deal with changes and technology issues that arose later in the program and contributed to antagonistic relations between the customer and supplier.

The conflicting agendas of participating companies frequently undid the intent of the contract. Each company had its own interests to safeguard regardless of the joint participation. ASC did not always have the in-house technical capacity to resolve issues, but because of the contractual arrangement, it was reluctant to go back to Kockums for changes, since this would involve paying Kockums more money.

The directed subcontract with Rockwell was anomalous. The government negotiated the contract and directed ASC to award it as a subcontract. At the outset, ASC did not even have the security clearance necessary to see the specifications of its own subcontract. Throughout the acquisition phase, ASC was responsible for managing the Rockwell contract. However, the Commonwealth often talked to Rockwell directly instead of involving ASC in the combat system negotiations. This undermined ASC's authority to manage the subcontract.

For the combat system, Rockwell led a consortium with Singer Librascope, French sonar manufacturer Thomson CSF, and Computer Sciences of Australia (CSA). Only Singer Librascope and Thomson had extensive submarine combat system experience. Singer Librascope had expected to write the system software without having to reveal its source code to Rockwell to avoid creating a competitor. Rockwell reacted by increasing CSA's work scope to also include writing the system software. In addition, Rockwell had problems with Thomson because of intellectual property concerns. Cut out of a major role, Singer Librascope completed its work quickly and delivered consoles before CSA's software was ready. Relationships between Rockwell and Thomson were adversarial. Both companies strictly followed the letter of their contracts, which resulted in their paths diverging rather than converging. While most equipment functioned satisfactorily alone, system integration failed and the combat system crashed regularly.

Accountability issues cropped up in 1993, when ASC grew concerned that the combat system was failing.[5] ASC unsuccessfully tried to declare Rockwell in default. Instead of allowing a default in the contract, the government instructed ASC to accept delivery of the combat system in multiple increments with increasing functionality and complexity.[6] Afterwards, ASC left the responsibility of managing Rockwell's system to the government.[7]

As a result of combat schedule slippage, the contract was amended to provide a two-stage delivery in 1991, so that submarine platform trials could proceed in advance of a fully compliant combat system. Then, in 1993, the contract was amended again.[8]

The combat system was still not ready in 1996 when the HMAS *Collins* was delivered by the contractor. In 1997, combat system shortcomings were eventually announced following post-delivery sea trials of HMAS *Collins*.[9]

Although there were multiple warnings that the combat system technology was not far enough along in its development, no actions were ever taken by the government to make fundamental changes in the configuration of the system of choice or the subcontractor. This reluctance by the government to change configuration released ASC

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5 Woolner, 2009.

6 McIntosh and Prescott, 1999.

7 Woolner, 2009.

8 McIntosh and Prescott, 1999.

9 McIntosh and Prescott, 1999.

and Rockwell from key responsibilities and made it nearly impossible to enforce system specifications.

The contract between ASC and Rockwell caused many issues throughout the program, not the least of which were the security arrangements that prevented ASC from seeing the combat system's specifications. Contract changes were difficult to accomplish during the process because the tools and processes to make the contract more feasible did not exist.

CHAPTER FIVE

Designing and Building the *Collins*-Class Vessels

Designing the *Collins*

Because Kockums had been selected as the design contractor, the design team was in Mälmo, Sweden—separated by more than 15,000 km and over eight time zones from the hull construction site in Adelaide and the project office in Canberra. This separation presented communication and data-sharing challenges. A team of 18 Australian designers was sent to Mälmo to work with the Swedish designers, and the RAN sent a 20-person team to supervise the design and clarify requirements. Kockums was designated the design authority responsible for initial design, design review, and internal design approval of material systems, and for the design of modifications or changes to a material system. When the RAN team and Kockums could not agree on an issue, it would go back to the project office in Canberra and often end up being turned into a contractual matter.

The design phase of the *Collins* was short because there was no concept/system design phase. When the contract was signed, the design of the submarine was approximately 2 percent complete. Despite the original goal of building a submarine that was currently in service with another country's navy, the *Collins* was basically a new submarine design with a number of technical risks. One risk was designing a submarine that would operate in a manner and environment very different from what Kockums was accustomed to.

Kockums' experience in designing boats for Baltic operations gave it an approach to submarine design that was not always consistent with the Australian concept of operations (CONOPS). There were large differences in the endurance requirement and operating environments for the Swedish and Australian submarine force. The Swedes ran their submarines for a week at a time, departing on Monday and returning to port on Friday. Thus, their subs were typically smaller with a lower usage rate and lower power requirements. The Australians, on the other hand, transited greater distances and were on station for months at a time, which had a number of implications for fuel storage, hotel services, and other hull design features. Additionally, Kockums was accustomed to designing for operations in the Baltic, where the waters are cold and relatively calm, which was problematic for Australia's salty, open-ocean environments and tropical waters.

This difference in CONOPS and environment ultimately led to some equipment and system decisions during design that would cause operational and support problems.[1]

Building the *Collins*

The *Collins* was the first class of submarines constructed in Australia. Although the RAN had experience with maintaining the *Oberon* class and had previously built commercial ships and some naval vessels, Australia's submarine construction capability had to be built from

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1 A prime example is the Hedemora diesel engine chosen for the propulsion system. The power required for the *Collins* and the desire to have three engines arranged side-by-side rather than four engines paired in two rows led to a significant modification of an existing engine. The Hedemora diesel in the *Collins* has 18 cylinders, modified from a 12-cylinder locomotive engine design. The *Collins* boats are the only diesel submarines with this particular engine. An earlier class of Swedish submarines uses V-12 Hedemora diesel engines, but Sweden subsequently specified other engines for its submarines designed after *Collins*. In 1998 a liaison with ASC visited Hedemora to try to resolve some of the problems with the engines and was shocked to see that the company only had 35 employees and was up for sale. Hedemora's ability to assist ASC was minimal, and Australia had to deal with the responsibilities of operating and supporting a unique engine that was a key to the submarines' success.

the ground up. Building the submarine required the "green-field" construction of an assembly facility at Port Adelaide in Southern Australia.

Construction of the hull began in 1989, when only 10 percent or so of the construction drawings were complete. ASC has stated that starting the *Collins* production before the design and drawings were much further complete was a fundamental mistake, resulting in costly modifications and rework when changes were made to the design.[2]

Although the design effort was concentrated in Mälmo, construction for the first boat was highly decentralized. The major construction was done in Adelaide and in Kockums shipyards (Kockums built some sections of the first-of-class *Collins*), but the initial propulsion motor was built in Champagne-sur-Seine in France,[3] the control system in Jönköpig in Sweden (by Saab Instruments), and the torpedo tubes and weapons discharge system in Victoria, Australia. The distance between the shipyards and the RAN in Canberra proved to be a problem for construction.

One rationale for choosing Kockums as the designer was its unique modular construction approach. The Kockums submarine construction facility at Mälmo demonstrated the benefits and success of modular construction. The modular construction techniques proved successful in building the *Collins*, especially considering that large modules or sections of the submarines were coming from multiple shipyards, including the Kockums yard in Sweden.

HMAS *Collins* was launched in 1993. Although the launch was impressive, it was mostly a façade set up for the press and dignitaries. At the time of the launch, the design was not yet completed, the pipe fabrication was not finished, and even some of the steel plates were just timber painted black. After the launch, construction continued for another 10 months; the boat was not completed until June 1994, well behind schedule. The project office attributed the delays to several

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[2] ASC, no date.

[3] Subsequent propulsion motors were built in Australia. Although detailed build plans were provided to the Australian manufacturer, the subsequent motors had several operational issues. This proved to be an example where "tribal knowledge" of the build process was critical to the success of the product.

factors—delays in the delivery of the combat system, difficulties in the final installation, and industrial disputes.[4]

During the build of the *Collins* submarines, ASC suffered a number of business, contract, and legal problems. The main issue involved Kockums as the subcontracted designer and part owner of ASC. Between 1998 and 2000, after the delivery of the first of the *Collins*-class boats, Kockums was losing a great deal of its capability and was finally sold to the German firm HDW. HDW promised to fix some of the issues with the *Collins*, but did not follow through. The Commonwealth decided to take complete ownership of ASC in 2000.

Initial Problems with the *Collins* Submarines

Once the *Collins* had been delivered, she continued to be fraught with delays and problems. The diesel engines had been a problem since the beginning, and remain so today.[5] Although multiple tests were done on the Hedemora diesel engine, the team failed to test it in salt water. The fuel system in any diesel submarine requires water to be added over time to compensate for the weight of the fuel burned. The key is to design a fuel system that precludes this water from reaching the engines. *Collins* had a complex fuel system that allowed water to enter the engine, partly a result of a faulty design. Swedish submarines have short patrols in calm, relatively fresh, water. When a similar design was used in the salty, open water in which Australian submarines operate, water was sucked into the engine. Salt water is more corrosive than fresh water, which exacerbated the problem. The crews and maintenance team were unprepared for this problem. Moreover, it has affected the ships' endurance, because the crew now must leave 30 percent of the fuel in the tank to prevent water contamination.[6]

The diesel engines have been unreliable and problematic. Between the initial delivery of HMAS *Collins* and October 1998, there were

[4] Yule and Woolner, 2008, p. 193.

[5] Dodd, 2010.

[6] McIntosh and Prescott, 1999.

more than 75 recorded defects against the diesel engine.[7] Some of the problems stemmed from the water-contaminated fuel, but poor design modifications, poor quality control, and poor subcontractor backup were also to blame.[8] Repairing these problems has not only affected cost and schedule, they have also hindered the performance of the ship and eaten into the operational time of the submarine.

Noise levels also proved to be a problem. First, the requirements for noise were not well laid out in the contract, perhaps because of a lack of technical understanding of noise issues. The operators wanted the boat to go faster at a quieter signature, but the contract was not changed. Adding to the problem was the lack of tools to measure submarine noise. Finally, in 1996 the RAN reported that the noise ranges were higher than expected, but there were arguments on whether the tests were accurate enough. The noise problems came from several factors—the flow of water over the hull, the shape of the casing, and cavitation from the propeller.

The propellers proved to be an additional problem. In 1998, the propellers started to develop fatigue cracks. Sonaston, the material used for the propellers, proved to be too brittle for boats operating in an open-ocean environment. At one point, a propeller blade was fractured three-quarters of the way through the root.

Other serious problems the *Collins* experienced were vibration on the periscopes, unreliable communication masts, and a poor propeller shaft seal. All these problems accumulated, and the schedule delays continued to affect the following ships throughout the program.

Collins Integrated Logistics Support

The RAN was ill prepared to take on the challenge of determining the ILS needed for the *Collins*. Furthermore, design and construction problems caused money to be moved from developing ILS procedures and products. The project underestimated the planning for in-service

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[7] McIntosh and Prescott, 1999.

[8] McIntosh and Prescott, 1999.

support requirements and largely assumed that the maintenance program would follow the procedures used to support the *Oberon* class, although adapted for *Collins*. Experienced submarine fleet engineers said that newer reliability centered maintenance concepts should be adopted, but no action was taken. According to the Australian National Audit Office (ANAO), the *Collins* class was put into service "without a validated strategy for the operational sustainment of the submarines throughout the life of the class and without a good understanding of the real cost for support of the complex submarine platform."[9] Specific problems included an inadequate maintenance regime, poor systems reliability, a need to rely on offshore design authorities and original equipment manufacturers, and technical knowledge deficits in the domestic workforce.[10]

The Role of a Parent Navy in Integrated Logistics Support

Through the 19th century and the first half of the 20th century, the Royal Navy acted as a "parent navy" to the RAN, providing platforms and support when necessary.[11] During this period, the RAN's focus was to secure Australia's maritime frontiers by protecting her ports, shipping, and trade routes. The RAN also served as an integral part of the Royal Navy by serving in all operational areas.

The *Oberons* were obtained from the United Kingdom but were serviced in Australia at the Cockatoo Island Dockyard. From 1974 through 1986, Cockatoo Island Dockyard was owned by Vickers Holdings Pty Limited, an Australian holding company of Vickers Limited, a UK shipbuilding and defense firm.[12] Many workers came to Australia from the United Kingdom to work on *Oberon* refits, and

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9 ANAO Audit Report No. 23, 2008–09.

10 ANAO Audit Report No. 23, 2008–09.

11 The Royal Australian Navy was established in 1911. Prior to that, the Royal Navy maintained a submarine squadron in Australia.

12 The History of Cockatoo Island Dockyard, no date. Cockatoo Island Dockyard was originally used as a dock for the Royal Navy, and was staffed with convicts who lived on the

the yard's experience with such business grew. Nevertheless, Vickers put Cockatoo Island up for sale in May 1987 and later announced that no further *Oberon* submarine refits would be done there. The RAN leaned on the expertise at Cockatoo as well as the Sydney submarine base expertise, since they were in such close proximity. Also, an open lane to UK technical expertise was available to the dockyard as necessary. The Cockatoo Island personnel, the base personnel, and access to UK resources (spares, design advice and approval) all contributed to successful *Oberon* refits and maintenance. As time went on, the RAN's and Cockatoo Island's sense of self-reliance grew, and their dependence on the UK for help diminished.

Not only did the RAN depend on overseas partners for support, it also leaned on the Royal Navy for training. At the start of the *Oberon* project, RAN personnel trained and served in Royal Navy submarines. This was a win-win situation because the RAN crew augmented the Royal Navy as it expanded its fleet and found itself short of personnel. In turn the RAN members learned how to operate and support submarines that were nearly identical to the RAN submarines.

As this partnership went on, submarine experience grew within the RAN, and it became less dependent on the Royal Navy. However, there was an agreement to always allow the UK access as long as the UK continued to operate *Oberon*s.

The Royal Navy provided dependable support until the Falklands War, when its resources became focused elsewhere. This, combined with the RAN's growing ability to support the *Oberon* class independently, particularly its ability to upgrade the combat system, gave the RAN confidence that it could build and manage a new class of submarine.

However, several aspects of managing a new submarine were different than the *Oberon* situation. First, because the *Oberons* were working submarines in the Royal Navy, UK industry and personnel knew how to deal with problems. The *Collins* was a completely new design, and therefore there were no Australians who knew the systems and

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island. The first ship to be built on Cockatoo Island for the RAN was HMAS *Warrego* in 1912. HMAS *Warrego* was built in pieces in Scotland and then reassembled at Cockatoo.

platforms. The RAN had to train its own crews for this new platform, an area in which it had minimal experience.

Second, there was no equivalent "*Oberon* Support" agreement, nor an equivalent "*Oberon* Club." The *Oberon* class was first constructed for the Royal Navy, and later vessels were constructed for Canada, Australia, Brazil, and Chile. This shared platform created a wealth of experience to call on and a community of experts who shared knowledge through the *Oberon* User's Group. For the *Collins* class, there were no "on call" experts who had already dealt with similar problems. The RAN thus was forced to start from scratch, which resulted in a much slower problem-solving process than anticipated.

Third, Cockatoo Island Dockyard was closed, its group of experienced personnel was disbanded, ASC was created, and the submarine base was moved from Sydney to Western Australia—losing many experienced people along the way. ASC was created on a green site, and while it hired some experienced people from Cockatoo Island, it had to build up a workforce almost from scratch.

All these actions created hardships for the RAN almost immediately, and with the new submarine came the new responsibility of being a parent navy. Although the RAN had some parent navy responsibilities during the *Oberon* period, the UK was always there to assist. For the first time, the RAN had to be completely responsible for all aspects of its submarine fleet.

A prime example of RAN being on its own is the Hedemora engine, used in all six *Collins*-class submarines. This was a departure from the *Oberon*'s engine, the ASR1 (Admiralty Standard Range 1), which was standard for all *Oberon*s in the UK, Canada, Australia, Brazil and Chile. Additionally, the *Oberon* predecessor, the *Porpoise* class, as well as the *Leopard*- and *Salisbury*-class frigates, were fitted with the ASR1. Thus, the RAN had plenty of experience to lean on with the *Oberon* engine. Not so with the Hedemora.

The hidden benefits that came with the relationship between the RAN and the Royal Navy during the *Oberon* time were either not realized or underestimated when the RAN decided on a new platform. The RAN anticipated that the Swedish Navy would fill the role of parent navy, but *Collins* ended up being very different from Swedish submarines—operating very differently from Swedish submarines in a very different environment. Once Australia decided to build a unique platform, it abandoned the team experience that the *Oberon* Club provided. It partnered with both new and existing industries and found that relying on them was problematic, as with the Hedemoras.

Training and Personnel

Originally, each *Collins* submarine had a crew of six officers and 36 enlisted personnel.[13] ASC provides training at the Submarine Training System Centre. ASC and the RAN have a five-year contract to manage and provide submarine training, spanning entry-level recruit training to advanced requalification platform training. Typically, 85–100 submariners come through the Submarine Training System Centre per year.[14]

The RAN has had difficulty manning its submarines. In 2008, the RAN experienced a submariner shortfall of 37 percent across all submarine ratings, with the greatest shortages in skills that are also in high demand in the mining areas in Western Australia.[15] This has created significant problems with achieving targets for unit-ready days and deployment cycles. In 2006 Australia's maritime commander, David Thomas, reported the RAN had to change its recruitment policy from recruiting within the RAN to "directly off the streets."[16]

The culture and structure of the RAN complicate submarine service recruiting. Historically, there has been a lack of career structure for submariners. Most high-ranking officers within the RAN are surface warfare officers, and submariners have had difficulties reaching two-star ranks. This lack of submarine experience, coupled with lack

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13 ASC Pty Ltd., 2008. The initial crew size has proven inadequate to operate the submarine. The *Collins* class currently has a crew of eight officers and 50 enlisted personnel.

14 ASC Pty Ltd., 2008.

15 ANAO Audit Report, 2009.

16 Banham, 2006.

of technical and logistics acumen at the decisionmaking level, affects the program.

Many crew members were not retained during the transition between the *Oberons* and the *Collins*. Although this stemmed from numerous factors, including relocation of the submarine base from the East to the West Coast, the lack of a sound platform transition plan is mostly to blame. Thus, the crew was not properly trained to operate the new boats. This remained the case in 2009, when only two of the six boats were operational. There are not enough crew members for all six submarines, which affects maintenance and support of the platforms. HMAS *Rankin* has no crew, and it is waiting to go into a full cycle docking (FCD). However, skeptics contend that *Rankin*'s FCD completion is low because there will be no crew to man the boat when it gets out of FCD unless the current recovery plan is successful. On the other hand, it is very difficult to recruit a crew if there is no platform on which to conduct training and professional development.

Under the build contract, ASC and its subcontractors were in charge of training the crew for the *Collins*. However it became clear that the quality of the training courses was affected by delays and the approach to the task. The training courses assumed that there was a great deal of redundancy and the equipment was in good shape, so the crew did not need to learn how to fix anything. This way of thinking proved to be incorrect.

Current Status of the *Collins* Class

The RAN currently has six *Collins* class submarines. The first (HMAS *Collins*) was delivered in 1996, and the final submarine (HMAS *Rankin*) was delivered in 2003, as shown in Table 5.1. The submarines are expected to have a 25- to 30-year lifespan. Sustainment of the *Collins* class includes maintenance, logistics, personnel training, and support services. In 2003, the Department of Defence entered into a \$3.5 billion, 25-year Through Life Support Agreement (TLSA) contract with ASC Pty Ltd for maintenance support and design services on the *Collins*-class submarines. The TLSA accounts for approximately 60

Table 5.1
***Collins*-Class Submarine Delivery Schedule**

Hull Name	Delivery Year
HMAS *Collins*	1996
HMAS *Farncomb*	1998
HMAS *Waller*	1999
HMAS *Dechaineux*	2001
HMAS *Sheehan*	2001
HMAS *Rankin*	2003

percent of the total sustainment costs. The rest of the costs are through contracts for combat systems, the Submarine Escape Training Facility, the Submarine Escape and Rescue Centre, and inventory with smaller suppliers.[17]

Media Coverage

Throughout the *Collins* development, the project was plagued by critical press coverage. Many Australians are familiar with the catch line "noisy as a rock concert," and the tagline "dud subs" that surfaced in 1998 after the supposed release of a U.S. Navy report. Although the noise problems were real, the amount of coverage that they received blatantly exaggerated them. In reality, the sound problems were relatively easy to fix; however, more serious problems, such as the combat system, existed and received less coverage. The amount of critical coverage greatly affected the perceptions of the project held by the general public and by influential government and military leaders in Australia.

[17] ANAO Audit Report, 2009.

Successes of the *Collins*

While the *Collins* faced and overcame numerous problems from conception to through-life support, the program also had successes. The RAN's Submarine Safety Program (SUBSAFE) is one of the *Collins* program's most successful aspects. SUBSAFE is a safety standard developed by the program office to certify and manage the operational safety of submarines.[18]

This safety program has been proven at sea. In 2007, it won the Best Workplace Health and Safety Management System award from the Department of Defence, which noted the program's clear management commitment and high degree of integration.[19]

High-tensile steel has been another *Collins* success. The procedures for making the steel—including its composition and the cooling temperatures—have been documented so they can be used again in the future. Oscar Hughes and the Defence Science and Technology

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[18] Woolner, 2009. Although there was no budget for this development, the project leadership considered submarine safety to be a priority. At this time, the RAN had no standard for submarine safety, so the American SUBSAFE program was used as a precedent. SUBSAFE systematically records, investigates, and implements corrections to identified hazards on a risk-based priority. See Australian Government Department of Defence, no date. SUBSAFE comprises eight elements: (1) material safety—which maintains the integrity of the SUBSAFE Certification Boundary to permit the submarine to recover from a credible flooding hazard condition; (2) quality systems—which detail the minimum requirements for processes and audits that must be carried out at all levels of submarine operation and logistic support; (3) escape and rescue—which ensure the submarines conform to the requirements of the RAN Submarine Escape and Rescue Policy; (4) combat survivability—which addresses the submarine's design and its ability to withstand underwater explosive shock and torpedo impact, the use of redundancy to maintain services affected by damage and other areas that might affect the submarine's ability to fight, such as crew training, flooding, fire fighting and toxic gas management and control; (5) weapons systems safety—which ensures the safe handling, stowage and discharge of all weapons carried in the submarines; (6) inspection test and trials—which demonstrate compliance with the specifications and the maintenance of SUBSAFE Certification; (7) human engineering—which optimizes performance of operator and maintenance personnel and ensures the health and safety of personnel in the working environment with particular emphasis on the management of hazardous materials; and (8) software safety—which ensures that software that contributes to system safety is appropriate to system employment and its integrity has been demonstrated. See Miller, 1998.

[19] Australian Government Department of Defence, no date.

Organisation (DSTO) worked together to select the steel and work on welding techniques. Steel and welding testing was done with DSTO. Part of the reason that the steel was so successful was that the procedures were very well understood.

Welding done in Australia has also been a success. The new workforce at ASC learned how to prep and weld the steel. The workers at Kockums were not following the specs or standards because they "already knew" how to weld steel, although this was new steel. The quality assurance process was never properly executed or audited at Kockums, which led to thousands of defects in the sections (300 and 600) of the boat built in Sweden.

The *Collins* class is often heralded as one of the most impressive diesel submarine in the world today. The *Collins* submarine has one of the most strenuous CONOPS of all diesel submarines, and overcoming all of the obstacles the program faced was not easy. Australia had never built a submarine, had never maintained a class by itself, and had never transitioned platforms by itself. All things considered, Australia pulled off a very impressive feat that offers many lessons for future programs.

CHAPTER SIX

Lessons from the *Collins* Program

Any time a person, organization, or country undertakes a complex task for the first time with little relevant background experience, there are bound to be risks that are underestimated or unknown, leading to problems during the program. This is certainly true of the *Collins* experience, and there are numerous lessons to inform future programs and decisionmakers. The *Collins* was the first submarine built in Australia and supported solely by the RAN. Despite numerous troubles and missteps, the construction program could be categorized as a success, and most would agree that, when operational, the *Collins*-class submarines are among the best performing conventional submarines in the world.

Lessons are appropriate at two levels—the relatively short-term and narrow focus of a specific program and the long-term, future strategic vision for the force and industrial base. To be useful, lessons should be categorized along different dimensions, although many lessons weave through whatever categorization is used. We discuss the programmatic and strategic lessons from the *Collins* program in terms of the overall support and management of the program, the impact of operational requirements on technology and risk, the contracting format and relationships that are established, the design and build of the submarine, and the planning for the ILS of the submarines. Most of the lessons can be traced to the information contained in the previous chapters. Some lessons, however, are general in nature and are based on the insights provided during the various interviews.

Supporting and Managing the Program

A necessary, but not sufficient condition for a program to be successful is that it be well managed and have broad support. Effective management and support must span the life of the program, from concept to disposal. There are several aspects to a well-managed and well-supported program, which we discuss next.

A new program must be adequately supported within the navy, across the government, by the scientific community, and by the public. Support must be both external to the program and internal within the navy and submarine community. Political support is most important for the advancement of a new acquisition program. Without the support of the politicians, sufficient funding may not be available to adequately conduct the program. Support must also come from the scientific community that possesses the technical knowledge needed to make informed decisions (using industry or allied partner technology expertise as needed) and from the public. One lesson from the *Collins* program is the need to effectively manage the media; the bad press that accompanied the *Collins* effort still taints the program in the mind of the general public. Below, we discuss the management of media relations and the inclusion of the scientific community in more detail. Finally, support must come from within the navy. The nonsubmarine portion of the RAN was not adequately supportive during the early stages of the *Collins* program.

Adequate support includes continuity in managing the program at various levels. During the *Collins* program, the head of procurement, the project office management, and the chief executive officer of the prime contractor were all replaced at one time or another. Changing leadership during a program can cause changes in goals and management strategies that could be detrimental to the success of the program. Personnel changes are inevitable, especially for military personnel. But such changes should be minimized to the extent possible; when new leadership is brought into a program—either on the contractor or the government side—it is helpful if the new leader was previously involved with the program rather than someone with little or no background in the program goals and strategies.

The program should be open and transparent to all, and should describe both successes and problems. Full disclosure during the program is necessary to obtain government, industry, and public support. There should be periodic feedback to the government decisionmakers and to the public on how the program is progressing, especially when there are unanticipated problems. In this regard, a good media management program is necessary. Bad press greatly and negatively affects the program, as was seen during the *Collins* program. Effective communications must be proactive, not reactive, in briefing the press, academia, and the state governments. Program managers must proactively ensure that the press is well informed of both the positive and negative issues and their associated implications and solutions, not react to them after only the bad press has been disseminated.

All appropriate organizations, commands, and personnel should be involved in the program from the beginning. The program and the procurement agency must be informed customers supported by adequate technical, operational, and management expertise. The program must have people from the fleet with experience in submarine operations and maintenance; people from the research and technical community knowledgeable in the areas of hull, mechanical, and electrical systems as well as propulsion, signature, and survivability issues; and people from the construction shipyard(s) who understand the potential problems with building certain aspects of a design to identify risks and solutions early and throughout the program.

One criticism of the *Collins* program is the absence of the technical community during the early stages of the program. The McIntosh and Prescott report specifically criticizes the lack of close coordination between various defense interests, specifically mentioning that the DSTO's role was not sufficiently defined at the outset. In addition to the technical community, the program office must involve operators, builders, and maintainers from the beginning of the program. Some of the problems with the *Collins* program might have been alleviated if it had used a design/build philosophy that involved the builders and key suppliers during the design stages of the program. Early involvement of the builders, as well as the operators and maintainers, helps identify requirements and potential problems up front and permits the identification of solutions to potential issues before they grow into significant problems during production and in-service operations and support.

Another problem often mentioned during our interviews was the lack of co-location of the appropriate organizations during the program. Part of getting the right organizations and personnel involved is having some degree of co-location of people from the scientific community, the designer, the builder, the operators, and the maintainers. This encourages engagement and teamwork among all parties. Modern communications can help bring people together from various locations, but face-to-face interactions are often necessary for effective decisionmaking.

Successful programs involve having experienced people in key management positions. This requires a strategy to grow people so they are experienced in various disciplines. The McIntosh and Prescott report states, "[T]he procurement organization must be structured on the most professional possible lines and provide attractive careers for all its staff . . . it creates opportunities for members of its staff to be seconded to large commercial organizations in Australia to get a different and very businesslike perspective on large complex procurements." One criticism often voiced during our interviews was the lack of a career structure for RAN submariners, which led to few submarine-experienced officers in decisionmaking positions in the RAN. This is a top-level, strategic lesson that must be implemented far in advance of any specific program. It goes beyond just submarine programs: The RAN must plan to provide relevant experiences to potential program managers, sending them to various operations and acquisition-related positions and giving them appropriate education in the academic community. This level of knowledge and expertise in the officer corps allows the RAN to be a informed customer.

The government and the RAN must take a long-term strategic view of the force and the industrial base. Again, this is a top-level lesson that goes beyond a specific program. A specific program is only one step in a successful military capability and the industrial capacity to provide and support that capability. Decisionmakers must take a long-term view and understand how a specific program nurtures and feeds into the overall strategic plan. A new submarine does not remain static once it is delivered to the force. Technologies change, new capabilities are needed, and new threats emerge and evolve. These changes require maintaining a capability edge so an existing platform can be updated with new technologies and new capabilities. The technical community and the industrial base that designs, builds, and maintains the fleet must be sustained so that they can provide the required capabilities when needed. This is especially true in the submarine community, where many skills are unique and cannot be supported by surface-ship programs.[1] The UK's *Astute* program suffered because of the atrophy of the design and build portions of the industrial base.[2] ASC was formed to design and build the *Collins*, but little thought was given to sustaining the new capability once the build program ended. A key lesson is that a new submarine development program produces more than a strategic military asset; it also contributes to domestic economic goals and is one part of a long-range operational and industrial base strategy.

Setting Operational Requirements

In many ways, the most important aspect of a new program entails the decisions made very early in the program. Those early decisions tend to hold throughout the program and affect the likelihood of program success or failure. Many of these early decisions involve setting the operational requirements for the platform, which are then translated to performance specifications that lead to technology choices to achieve the desired performance. The operational and performance requirements for the *Collins* were set very early and, especially in the case of the combat system, greatly impacted the overall design and build of the submarines.

Program managers must understand the current state of technology in those areas that apply to their program. The desired operational performance will drive the characteristics of the platform and the technologies needed to achieve the performance goals. Program managers must

1 See Schank et al., 2007.

2 See Schank et al., 2005.

be supported by a technical community (as mentioned previously) that completely understands the state of those technologies that are important to the program, where needed technologies exist, and where technologies must be significantly advanced.[3] Relying too heavily on significant advances in technology will lead to risks in achieving the desired operational capabilities. The *Collins* program began with a desire to base the design on an existing submarine or one that would soon be in service with another country's navy. Unfortunately, neither Kockums nor the RAN fully appreciated the difference between the operational requirements of the *Collins* and the capabilities of existing conventional submarines. The end result was basically a new submarine design that pushed technology limits, especially in the case of the combat system. The program did not readily understand or plan for the technical risks that were involved in such a radical new design effort.

Program managers must understand how a platform's operational requirements affect technologies, risks, and costs. It is important for program managers not only to know the current state of various technologies but also to understand how changes to operational requirements relate to the technology levels that are available. That is, if certain operational goals are beyond the state of current technology, what operational capabilities can be support by existing technologies? This relates to trade-offs between operational requirements and technological risks (and associated cost and schedule implications). Again, this is where both operators and the technical community are important during the early stages of a program. The developmental platform and the developmental combat system in the *Collins* led to a high degree of risk. Backing off requirements slightly, especially with the combat system, could have significantly reduced those risks. Therefore, the program must understand the technical boundaries and the risks inherent in an evolutionary versus a revolutionary strategy. Existing systems can be scaled to some degree. However, scaling an existing system too far

[3] Australia may not currently have the breadth and depth of submarine related expertise in its technical community that will be required for a new submarine program. An allied technological partner may be required to supplement in-country technical resources.

leads to difficulties and ultimately results in entirely new systems or significant problems.

Program managers must understand that when they specify an operational requirement they must also specify how to test for the achievement of that requirement. Stating an operational requirement is the first step in setting program goals. But that first step must be complemented by a plan for how to understand whether the platform meets the stated operational requirement. This typically involves test procedures, including who will do the testing, how the test will be conducted, and how success or failure will be measured. Although it is often difficult to plan for testing early in a program, doing so is necessary to ensure that all parties agree on the processes to measure how the performance of the platform meets operational capability objectives. It was often mentioned in our interviews that inadequate testing of the Hedemora diesel engine led to problems during operations.

Establishing an Acquisition and Contracting Environment

Establishing an open and fair contracting environment and understanding the risks involved with desired operational capabilities are the two most important aspects of any program. Mistakes made in these two areas will resonate throughout the life of the program. The contracting environment covers a range of issues, including the type of contract, the specifics within the contract, incentives, the decisionmaking process when issues arise, and the payment schedule. In this area, a number of lessons from the *Collins* program are important for future programs. These lessons, discussed below, often overlap, but they all aim for a fair, collegial partnership among the program office, the prime contractor, and the subcontractors.

Establish a collegial and interactive environment with the industrial base organizations. Most would agree that the relationship between the program office and ASC, the prime contractor, was very strained during the conduct of the *Collins* program.[4] The strained relationship grew out of many issues in the contracting environment and greatly affected the conduct of the program. We next describe some specific lessons that will help to create the desired environment and relationships between all parties.

Use a contract structure with appropriate provisions for handling the technical risks in the program. Although the initial desire was to base the *Collins* on an existing submarine design, the program actually developed a unique platform design, especially with the combat system. The resulting design had a number of technical risks that promised unpredictable outcomes and the need for flexibility in the program. Unfortunately, the decision was made to use a fixed-price contract that greatly limited the flexibility both parties needed when problems emerged. The fixed-price contract used for the *Collins* program had poorly defined specifications. ASC had no motivation to provide more than what it interpreted as its obligations, and the Commonwealth took the position that it would pay no more than the original contract price and was afraid to enforce the specifications for fear of being liable for a contract change it could not pay for. The collegial and open environment necessary for a development program was negated by the *Collins* contract structure.

Fixed-price contracts are appropriate when there is little risk and uncertainty (e.g., when technologies are mature and when specifications are well-defined) and when changes to the design or build are not anticipated. While the government can try to place all risk on a contractor through use of a fixed-price contract, the government ultimately holds all program risk. It is far better to structure a contract in which the contractor is responsible for risks under his or her con-

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4 The McIntosh and Prescott report stated ". . . the positions of the parties (the operational RAN, the procurement project office, the in-service support project team, the prime contractor, and the principal sub-contractors) are certainly far more antagonistic, defensive, uncooperative and at cross-purposes than should be the case in a project like this." See McIntosh and Prescott, 1999, p. 8. That report also includes the following observation by Lloyds Register: "In looking at ASC's conduct throughout the review period, there appears to be an underlying atmosphere of confrontation and contempt for their customer's wishes, with no visible recognition that their customer was and is unhappy and what could ASC do to rectify the matter.

trol (labor and overhead rates, productivity, materiel costs, etc.) and the government is responsible for risks beyond the contractor's control (inflation, changing requirements, changes in law, etc.). Otherwise, contractors will greatly increase their bid prices to accommodate risks that they cannot control. Appropriate cost-sharing provisions can be drafted to handle risks that neither party controls or that both parties have equal influence over (technology changes, acts of God, energy shortages, etc.).

Any contract, whether fixed-price or cost-plus, must have adequate incentives for the contractor to "do better." Again, the *Collins* contract lacked such incentives. The lesson here is that technical risks must be identified early and much thought must be given to deciding, with industry, the appropriate form of the contract and the incentive and risk sharing clauses to be built into the contract. Getting this wrong, as happened in the case of the *Collins*, can almost guarantee problems with the conduct of the program and the relationships between the Commonwealth and the contractor.

Define contract roles and responsibilities, especially between the prime contractor and the subcontractors. One issue that plagued the *Collins* program was the relationship, or lack of one, between ASC, the platform prime, and Rockwell, the combat system prime. The Commonwealth negotiated the contract with Rockwell, yet it made ASC the prime contractor responsible for the successful delivery of the combat system even though ASC played no role in choosing Rockwell and did not even have access to the classified specifications. Furthermore, when problems with the development of the combat system emerged, ASC wanted to hold Rockwell in default but was prohibited from taking that step by the Commonwealth. From that point on, ASC took a hands-off approach and held the Commonwealth liable for delays in delivery of the combat system.

It is important that the roles, responsibilities, and relationships between all parties be clearly defined and agreed upon early in the program. When cooperation between contractors is essential to the success of a program, the government must actively manage their interactions and/or appropriately incentivize them to cooperate. Problems between contractors and subcontractors demand early attention to avoid subsequent greater problems and additional costs. Furthermore, the Commonwealth should not undermine the authority of the prime by dealing with subcontractors without including the prime.

Specify desired performance requirements and how to test that they are achieved. The Commonwealth should state the desired performance capabilities of the platform but should avoid specifying how those performance requirements should be achieved unless a significant benefit or risk is being managed. The prime contractor should have the ability to decide how best to meet performance requirements. Unfortunately, the *Collins* contract imposed both performance criteria and detailed specifications on how the performance should be achieved. The contract was a mix of requirements and specific solutions, and in some cases the solutions could not meet the requirements. This became a problem with the combat system (e.g., specifying the use of the ADA programming language[5]), the propeller (e.g., specifying the use of Sonoston), and the periscopes (e.g., the use of the supplier of the *Oberon* periscopes).

At times, there will be a benefit in designating a preferred provider or material. In those instances, the prime contractor should have the expertise to evaluate the requirement and suggest alternatives if appropriate.

Specifying performance requirements is not sufficient; how to test that the design meets those requirements must also be outlined in the contract. Unfortunately, adequate testing procedures were not developed or enforced for the *Collins* program. For example, comprehensive tank testing of the hull design was not specified or accomplished, and the Hedemora engine configuration installed on *Collins* was not fully tested before the submarines went to sea. Understanding and specifying adequate test procedures is an area where the involvement of the technical community is especially important.

Develop a timely and thorough decisionmaking process. Issues arise during the conduct of a program, and most issues will require timely

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[5] The *Collins* program was not alone in specifying the Ada programming language. The United States also specified Ada for its AN/BSY-2 combat system on the *Seawolf* submarine.

decisions. With the *Collins* program, an ANAO report stated: “Many quality problems may have been prevented but, repeatedly, when risks emerged, there was a general lack of decisive action by the Project Office to put sufficient commercial pressure on the contractor to correct the situation and protect the Commonwealth’s interests.”[6] It is important that a program have a decisionmaking process in place, with the appropriate checks and balances, that involves all applicable organizations—the RAN, the technical community, the program office, and the contractor. This process must be thorough in addressing all the appropriate issues and their impact on cost, schedule, and performance. It must also be timely in addressing those issues so as not to delay the program schedule or add cost due to schedule delays.

Establish agreed-upon tracking mechanisms and payment schedules. One shortcoming of the *Collins* program was paying the contractor the majority of the funds well before the project was complete. This led to little or no funds being available to handle problems as they arose later in the program. Also, the program office became aware of difficulties and problems too late in the process and was unable to make decisions that could have resulted in less costly corrections. It is important, therefore, to have an effective system for tracking progress and a payment schedule that is both tied to clearly defined milestones and that reserves adequate funds to handle difficulties that occur later in the program.

Develop a process to manage changes. Changes invariably occur during any program. Changes may be proposed in the desired performance of the platform, in the systems and equipment used to achieve performance, in the schedule of the project, or in the responsibilities of the various organizations involved in the design, build, and testing of the platform. Management structures must be in place to deal with any of the proposed contract changes that occur during the conduct of the program. Changes may affect cost, schedule, or capability. It is important that the program office understand the impact of proposed changes and have a procedure in place to approve or reject proposed changes. Understanding the impact of proposed changes requires the

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6 ANAO, 1997, page ix–x.

involvement of the technical community and the cost estimation community as well as the contractor and operational community. When funding is limited, changes that result in increased costs must be especially examined and managed.

Include an adequate contingency pool in the contract. One criticism of the *Collins* program was the lack of an adequate contingency to manage risks and the changes that come about in any program. Where normally a complex project, such as the *Collins*, would have a contingency fund on the order of 10 to 15 percent, the *Collins* contract had only a 2.5 percent contingency fund. The lack of an adequate contingency with agreed processes for disbursement adversely affected relations between the customer and the supplier, limiting what the program office or the contractor could do when problems arose.[7] The size of the contingency fund is related to the technical risks in the project—more risks require larger contingencies.

Designing and Building the Submarines

Many of the lessons from the *Collins* program described above are also applicable for the design and construction phases of a new program. It is important to get all the right organizations—operators, maintainers, and the technical community—involved throughout a program to understand how operational requirements affect design and construction and to plan for the appropriate testing of the systems and platform so that requirements are met. Therefore, several lessons described repeat those described previously.

Involve builders, maintainers, operators, and the technical community in the design process. A "design/build" process should be adopted during the design of a new submarine. This involves having the builders actively involved in the design process to ensure that what is designed can be built in an efficient manner. This lesson also applies to the *Collins* program because the design was undertaken by a foreign firm, Kockums, which was not actively involved in building the submarines.

[7] Woolner, 2009.

Design/build really goes further than merely involving builders in the design process. The design should also be informed by operators, key suppliers, maintainers, and the technical community. Therefore, it is important to think of the design team as a collaboration of submarine draftsmen and design engineers with inputs from those who must build to the design, operate the submarine, and maintain it. This collaboration should extend throughout the duration of the design program.

Choose a design organization with knowledge of the operating environment. One problem with the *Collins* program was a lack of appreciation of the demands of the concept of operations and the operating environment by the design organization. Kockums was a successful designer of submarines for the Swedish Navy, but those submarines operated in a far different manner and in a different environment from what was planned for the *Collins* boats. The Swedish Navy, like most European navies, goes on short patrols of a week or less, and its submarines primarily remain in one area for surveillance exercises. The *Collins* submarines were expected to operate for months at a time, deploying thousands of miles to their area of operations. Also, the Swedish submarines operated in the relatively cold and calm waters of the Baltic Sea. The *Collins* boats operate from tropical to open ocean waters. These very different operating environments require different equipment and different procedures for operating the equipment. Therefore, it is important for the design organization to fully understand and appreciate the way the new submarines will operate and the impact of the operational environment on the design of the boats. If the design organization is not familiar with the concept of operations or the operating environment, a technology partner with that knowledge is needed.

Listen to the technical community when it raises concerns about the risks involved in a design. Although this lesson has been raised more than once in slightly different ways, it is important not only to have the technical community involved in the design process but also to listen and react to the concerns it may raise. The degree to which existing technology is "pushed" in a new design will affect the risks to cost, schedule, and performance of the end platform. The technical community should understand the state of technology and the degree to which a new design extends that technology. The combat system for the *Col-*

lins is one example in which the program tried to reach too far from a technology perspective with less than satisfying results. The technical community consulted during a new design effort should extend beyond in-country resources to include the technical assets of partner nations. In some areas, especially technical areas not encompassed in previous programs, other countries may have a deeper and better understanding of the technology and the risks. Air-independent propulsion is an example of a technology area where the Australian technical community may have some knowledge but very limited experience.

Develop realistic estimates of the costs to build the new design. Although the *Collins* program largely stayed within the budget established for the program, the fixed-price contracting environment often resulted in forgoing needed changes and improvements during the design and build of the submarines. A new program must fully understand the likely costs to design and build the end product and, as mentioned above, must be able to incorporate important modifications that evolve due to changes in operational requirements or in the technologies used in the platform. This requires a thorough and sound estimate of costs, with funds for any contingencies that may arise. The *Collins* program was not supported by an independent cost-estimating process that fully understood the potential costs and risks. Such a cost estimating capability should be established in either the RAN or the Australian Department of Defence.

Design for the removal and replacement of equipment. The operational life of a submarine platform is typically greater than the life of some of the technologies incorporated in the submarine design. This is especially true for command, control, communications, computing, and intelligence (C4I) equipment. One problem the *Collins* submarines currently face is the removal and replacement of the large generators and other equipment. Adequate access paths and removal hatches were not included in the design, requiring large hull cuts to remove and replace equipment that requires repair or has become obsolete. The design of the submarine should anticipate the need to remove and replace large pieces of equipment and should include access paths and hatches to facilitate such removals. For C4I equipment, standard racks and connections should be incorporated into the design.[8]

Consider potential problems with foreign suppliers when designing the submarine. The *Collins* program relied on a number of foreign suppliers for key equipment. Often, a lead item would be built in another country and then production drawings would be provided to an Australian company to build the remaining items. Although, on the surface, this transfer of build processes should work, there were examples where the "tribal knowledge" of the build procedures was not addressed solely by the construction drawings and plans. The electric generators, designed by a French company, present a prime example of problems that emerged because the Australian company lacked the knowledge or specialty manufacturing equipment or systems required to build them. The Hedemora engines are another example of a foreign supplier not being able to adequately address the problems that emerged with the engines. If foreign suppliers are chosen for key equipment in a new program, there should be assurances that they are economically viable and will remain so during the operational life of the submarines. Also, if equipment designed by a foreign organization will be built in Australia, personnel from the foreign supplier should interact, preferably in Australia, with the company building the equipment to ensure that the detailed knowledge needed beyond that captured on design drawings is provided.

Supplier issues go beyond companies outside of Australia. An adequate supplier network inside Australia must also be developed and nurtured to ensure that the vendor base exists when needed. Maintaining an adequate vendor base is the responsibility of both the government and the shipbuilder since some parts and equipment are bought and provided to a program by both parties.

Specify adequate design margins and manage those margins during the design and build of the submarines. A new submarine design must include adequate margins for weight, power, cooling, and bandwidth, and those margins must be closely managed during the design, build, and operation of the submarines. New ships and submarines typically

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8 See Schank et al., 2009, for a discussion of controlling the C4I upgrade costs on ships.

start with what are believed to be adequate design margins, but those margins are often consumed during the design and build process or very early in the platform's life. This is a problem the *Collins* submarines have experienced to some extent. Without adequate margins, modernizing and upgrading equipment may not be possible. New power and cooling plants may be needed, but these new plants may exceed available weight margins. Existing systems may be downgraded or ship operations may be constrained if adequate margins are not available.

Complete the majority of the design drawings before construction begins. One very important lesson for the build of a new submarine is to ensure that the majority of the design drawings are complete before construction begins.[9] For *Collins*, only 10 percent of the drawings were done when construction started. The result was significant rework and construction changes as variations were made to the design. There is often a rush to remain on schedule or to show progress to the government or the public. It is far better to delay construction to ensure that the design is largely complete rather than risk the costly rework and changes typically resulting from an immature design. Use of three-dimensional product models can facilitate the design/build process, but these models must be completed early to support material ordering and downloading of manufacturing data to numeric controlled machinery. Early completion of a three-dimensional product model ensures that all pieces fit and minimizes expensive rework. As an example, the U.S. *Virginia* program had the basic arrangements finalized and 80 percent of the drawings complete before construction of the lead ship began.

Develop a thorough and adequate testing program. We mentioned previously that a new program must specify not only the desired operational requirements but also test procedures to ensure those requirements have been met. The testing procedures should be developed during the design and build portion of the program. Testing should involve the design and build organization(s) as well as the technical community and the RAN.

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[9] The majority of a new design should also be complete if competition is envisioned for the construction of the submarine.

Ensure that intellectual property rights are obtained so the submarine can be properly modernized and supported during its operational life. One problem that hindered the *Collins* program was the lack of the intellectual property (IP) rights to the design of the basic platform and much of the fitted equipment. Not having the rights to *Collins* IP on future designs may constrain the design effort for the new submarine class that will replace the *Collins*. Although Kockums and the DoD reached a settlement in 2004 that provided ASC and its subcontractors access to Kockums' IP, it still protected Kockums' proprietary information to the point that no intellectual property from the *Collins* can be used in a new Australian submarine design. The McIntosh and Prescott report touched on the need for IP rights being available to DoD, stating "(f)ailure to either own or have unfettered use of technology limits the alternatives open to the buyer when the supplier fails to produce and also more generally."[10]

Planning for Integrated Logistics Support

The current problems with the operational availability of the *Collins* class largely resulted from the lack of developing a thorough ILS plan during the design and construction of the submarines. Although ILS planning was included in the original contract with ASC, funding for the development of the plan was systematically reduced to address other issues that emerged during design and construction. A strategic view of ILS early in the program was particularly needed because the RAN was thrust into the unfamiliar role of a parent navy with the *Collins*. The original plan of "business as usual" failed to consider the unique requirements for maintaining the submarines and training the crews. Although logistics support occurs more than a decade from the initial design of the submarine, early planning for ILS must inform the design and construction of the submarines and the establishment of the facilities, contracts, and procedures to ensure the desired level of operational availability.

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[10] McIntosh and Prescott, 1999, p. 15.

Establish a strategic plan for ILS during the design phase of a new program. In its 2008–09 report, the ANAO stated "the *Collins* class was introduced into service without a validated strategy for the operational sustainment of the submarines throughout the life of the class and without a good understanding of the real cost for support of the complex submarine platform."[11] A strategic plan for ILS must be started early in the program, preferably during the design phase. The program must be able to specify what logistics support is needed, when it is needed, and where it will be provided. The program office, in conjunction with the prime contractor, the technical community, and the operating force, must drive the solutions to the ILS problem. It cannot sit back and expect a good solution to unfold without the proper analysis and input on its part. As mentioned in the design and build lessons, personnel from the organizations responsible for maintaining the submarine should be involved in the design process to ensure that what is ultimately built can be efficiently and effectively supported. The strategic plan should encompass a number of issues, as discussed next.

Specify the concept of operations and maintenance of the submarine. The strategic plan for ILS must start with a concept of how the submarines will be operated and maintained. Desired operational concepts are part of setting the requirements for the platform and factor into the design of the platform. The operational concepts must recognize that the submarine will require time for preventive and corrective maintenance and for equipment modernizations. The end result should be a periodic cycle of training, operations, and maintenance that holds throughout the life of the submarine. The development of the concept of operations and maintenance must involve the operators as well as the maintainers.

Understand the reliability of the equipment and the need for preventive and corrective maintenance. Developing a maintenance plan requires a good understanding of the reliability and maintainability of the equipment and the need for corrosion control and fatigue life management of the hull. This involves frequent interactions with the design authorities and the original equipment manufacturers (OEMs)

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[11] ANAO, 2009, p. 12.

to obtain the needed data and information. It also involves a thorough understanding, informed by a robust database, of the reliability and maintainability of any existing inventory equipment used in the new platform. Care must be taken when the design authority or the OEMs are not Australian companies. The 2008–09 ANAO report cautioned, "(t)he reliance on offshore Design Authorities and original equipment manufacturers (OEMs) has meant a convoluted, time consuming and hence costly logistics chain."[12]

Determine the "when, where, and who" for maintenance, modernization, and training. The strategic plan for ILS should include when maintenance, modernization, and training will be performed, where the activities will take place, and which organizations will perform those activities. Equipment reliability and the need for corrosion control will factor into when maintenance should be performed. Some maintenance will be the responsibility of the crew or support staff at the operating base; higher-level maintenance and modernization will be the responsibility of government or private-sector organizations and will be accomplished either at the operating base or at a shipyard. As discussed above, the end result should be a thorough plan for maintenance and modernization activities throughout the life of the submarine.

Recognize and plan for equipment modernization during the operational life of the submarine. It is inevitable that some equipment on the submarine, especially electronic equipment, will require updates during the life of the submarine. It is important that future equipment modernizations be part of the strategic ILS plan. Modernizations may involve the higher-level maintenance organization but will more likely involve the OEMs. Electronic equipment may require a time-phased program of upgrades involving both hardware and software. Setting periodic upgrade periods for hardware and software will establish a drumbeat of modernizations throughout the program.

Consider ILS from a navy-wide rather than a program perspective. ILS must be considered at the force level rather than at the specific program level. There will be demands on maintenance and training resources from other submarines (i.e., those being replaced by the new

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[12] ANAO, 2009, p. 43.

program) as well as surface ships in the RAN. The new program must recognize these other demands and plan accordingly. This is especially important for limited maintenance facilities, such as drydocks, that are used across several classes of ships or submarines.

Establish a planning yard function and develop a maintenance and reliability database. The original plans for ILS are likely to be modified as experience is gained on the reliability and maintainability of the equipment. Some equipment may require more maintenance than originally thought; other equipment may prove to be more reliable or easier to maintain. Establishing a planning yard organization that tracks maintenance and establishes future workloads is important to ensure that the right maintenance is done at the right times. This planning yard function can be performed by a government organization or by a private sector firm. Because the value of accurate data for efficient and effective asset management is extremely high, a key function of the planning yard is to monitor and update the database of the maintenance history of the new submarine. Another function is to stay in constant contact with the design authorities and OEMs to understand any changes in the platform or the equipment maintenance requirements and procedures.

Plan for crew training and transition of the fleet. The ILS plan must also include the "when, where, and who" for training activities. As with maintenance, some training will occur at the operating base while other training will be accomplished at centralized facilities. Some training may be done by the RAN; other training may be performed by a government or private-sector firm. When establishing the training plan, it is important to consider the transition of crews and personnel from an existing platform to the new submarine class. Also, a crew should be assigned to a submarine during construction so that the personnel can become familiar with the submarine and its systems and provide feedback during the build process. When a new submarine is delivered to the RAN, its crew should have been with the boat for a long enough time to become familiar with all the operating procedures. Part of the training plan should include when and how simulators or other training devices will be used to accomplish the training.

Provide and maintain adequate funding to develop the ILS plan. Most important, there must be sufficient funds to develop the strategic ILS plan that are "protected" during the design and build of the platforms. The original funding for the *Collins* program was systematically reduced to address other emerging problems during the design and build of the boats, which resulted in the lack of a thorough strategic ILS plan when the submarines entered service. The end result mentioned by ANAO and others is problems with maintenance and training for the *Collins*-class boats.

Summary

In this chapter, we have listed numerous lessons from the *Collins* program. Many of them have a central theme—involve knowledgeable people from various technical and operational organizations in an open and interactive environment. Designing and building a submarine is one of the most complex undertakings for a new program. It requires careful management and oversight and a delegation of roles and responsibilities that recognizes who—the shipbuilder or the government—is best positioned to manage risks.

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