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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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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]

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[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

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[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.