FUTURE SUBMARINE INDUSTRY SKILLS PLAN
A PLAN FOR THE NAVAL SHIPBUILDING INDUSTRY

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A PLAN FOR THE NAVAL SHIPBUILDING INDUSTRY

Australian Government
Department of Defence
Defence Materiel Organisation

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A PLAN FOR THE NAVAL SHIPBUILDING INDUSTRY

Australian Government
Department of Defence
Defence Materiel Organisation

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FOREWORD
WARREN KING & ANDREW CAWLEY

THE AUSTRALIAN GOVERNMENT HAS COMMISSIONED THIS PLAN BECAUSE OF THE IMPORTANCE OF THE NAVAL SHIPBUILDING INDUSTRY TO THE NATIONAL SECURITY OF AUSTRALIA. AUSTRALIA IS A MARITIME NATION, WITH INTERESTS THAT STRETCH FROM ANTARCTICA TO THE TROPICS. THE ROYAL AUSTRALIAN NAVY PLAYS A KEY ROLE IN MAINTAINING OUR INTERESTS AND SECURITY OVER THAT VAST AREA. THEY COULD NOT DO IT WITHOUT THE AUSTRALIAN NAVAL SHIPBUILDING INDUSTRY, COMPANIES BOTH BIG AND SMALL, AND THE THOUSANDS OF SKILLED MEN AND WOMEN THAT CONTRIBUTE TO THAT WORK.

While the plan has an end goal of preparing for the future submarine project, this plan covers all naval shipbuilding projects because the organisations, people and skills involved are inextricably linked.

Shipbuilding is about skilled people working on design, production engineering, production, testing and delivery of warships and their combat and platform systems. Shipbuilding is about the creation of highly complex computer programs, and integrating them with other software systems; the manufacture of large hull structures and integration of powerful machinery and a multitude of equipment.

Through projects like ANZAC and Collins, and now the Air Warfare Destroyer and Landing Helicopter Dock warships, Australia is on the right track to developing a world class, competitive naval shipbuilding industry. There is more work to be done to build the high performing industry that Australia needs to support Navy. Industry needs to keep growing its skills and experience; and through practice and investment become more proficient and more productive. We believe that these goals are well within this country's ability.

This plan sets out principles to improve the planning of the whole scheme of future naval shipbuilding projects. Plans can be optimised to deliver warships when required as well as foster the development of industry skills, improve productivity and so reduce the costs and risks associated with these naval shipbuilding projects. This benefits the Australian Defence Force, Government,industry and ultimately the Australian people. It helps the nation and protects our security. Achieving the potential described in this plan will take dedicated and persistent effort, we need to protect against complacency and any assumption that improvement will just occur. We have to make it happen and this plan is just the first step.

We appreciate the opportunity the Minister for Defence and the Minister for Defence Materiel have provided in asking the DMO to prepare this plan. We would also like to take this opportunity to thank our colleagues in Defence, David Mortimer and all the members of the Expert Industry Panel for their time and effort in helping to develop this plan. Their contributions have been invaluable.

Warren King

WARREN KING
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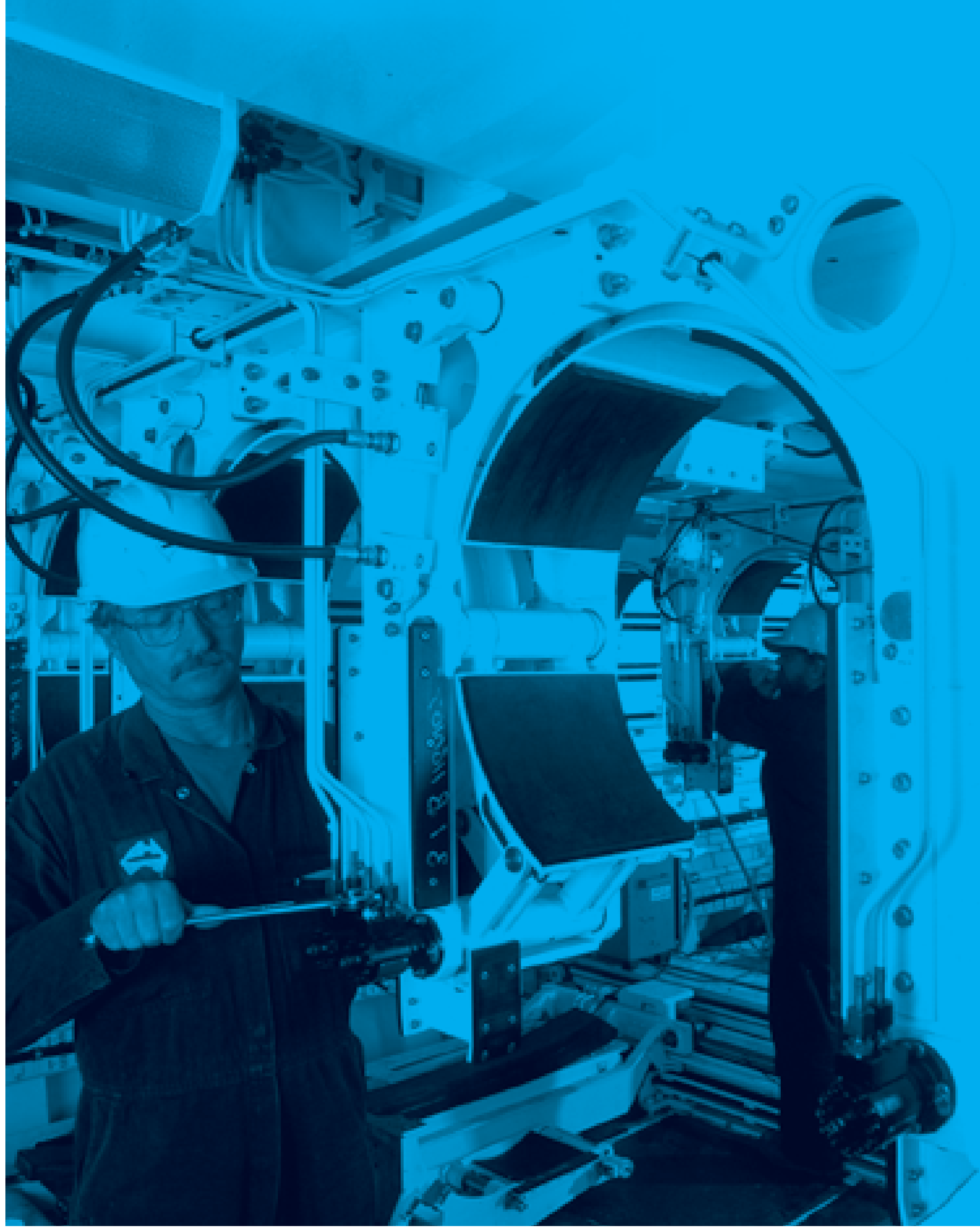
15 March 2013



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CHAIRMAN, EXPERT INDUSTRY PANEL DAVID MORTIMER

WE HAVE BEEN GIVEN A GREAT OPPORTUNITY BY THE AUSTRALIAN GOVERNMENT, A CHANCE TO BUILD A STRONG NAVAL SHIPBUILDING INDUSTRY IN THIS COUNTRY, A CAPABILITY THAT WILL PROTECT AUSTRALIA'S NATIONAL SECURITY.

Within a month of the terms of reference for the Future Submarine Industry Skills Plan being released in early May of 2012, I chaired the first meeting of the Expert Industry Panel at Parliament House. It was the first time the heads of the shipyards, systems houses, unions, industry groups and government bodies sat down together and looked at the current state of naval shipbuilding in Australia, the problems we face and what we could do to fix it.

One thing I asked from each of these leaders then was the need for them personally to be involved in the Panel. They had to act in a cooperative, open manner and not out of commercial self interest. The future of naval shipbuilding in this country is a serious matter and any hope of resolving the issues the industry faces requires a serious commitment from these leaders. I must say they responded superbly: even though busy, they attended meetings, engaged in an informed way in the discussions and provided every assistance to the team developing the report. I would like to thank them here for their time and efforts so far. This report would not be as informative as it is without so much help from industry.

If we are really going to make something out of this report, that cooperation and commitment must continue. Without it, the plan will not succeed. We can no longer afford to acquire new defence capabilities on a project by project basis, as we have done in the past. We need to look at our acquisition program as a whole, and think about planning for the long term. The naval shipbuilding industry has enormous potential to do better for Defence given the chance. Government and Defence must develop a long term acquisition schedule that provides a fairly steady flow of work, not one that overloads industrial capacity one decade and allows it to wither the next. In return for certainty in the schedule, Industry must commit to benchmarking and substantially improving productivity, increasing skills, building as well as maintaining an experienced workforce. With predictable and practical schedules, with improvements to productivity, Australia will have a shipbuilding industry that can deliver ships to the Royal Australian Navy cheaply and reliably.

We have a real chance to create something that will benefit Defence, industry and Australia. We must not be afraid to seize the opportunity.

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DAVID MORTIMER AO
CHAIR, EXPERT INDUSTRY PANEL

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INTRODUCTION

AUSTRALIA IS PREPARING TO EMBARK ON ITS BIGGEST DEFENCE ACQUISITION: TWELVE CONVENTIONAL SUBMARINES THAT WILL BE ASSEMBLED IN SOUTH AUSTRALIA.

The Australian naval shipbuilding industry, that is the designers, the systems developers and integrators as well as the ship construction companies, must be ready before the submarine project starts building what will be the most complex piece of equipment that the Australian Defence Force will use. We can only do that through proper planning and preparation.

This report, entitled the Future Submarine Industry Skills Plan, outlines what Defence and the shipbuilding industry can do to prepare for that first day. This Plan and its recommendations are an input into the 2013 Defence White Paper where Government will outline its decisions regarding future naval projects. The Defence White Paper in turn will inform the Defence Capability Plan 2013.

With the shipbuilding projects currently underway in this country, we are starting from a good base. Our designers have had experience in designing warships, and in developing and adapting established designs. Systems teams have worked on developing and integrating combat and platform systems into our current fleet and the new warships that are coming into service. Our major naval shipyards have the capacity to build the future fleet outlined in the Defence Capability Plan. The people working in those shipyards have developed sets of skills and experience that will grow further by working on other naval projects. By keeping those skills and experience active in the industry, it will become more productive and proficient.

If we are going to build submarines in this country, we cannot afford to lose the skills and experience we already have here. Defence must understand the challenges that face industry and provide long term predictable work that allows industry to develop capabilities and make investments for the future.

With Defence and industry working together, Australia can have a naval shipbuilding industry that is efficient, productive and will be capable of delivering the warships the Royal Australian Navy needs.

EXECUTIVE SUMMARY

TODAY AROUND 4,000 PEOPLE ARE BUILDING WARSHIPS IN AUSTRALIA. THESE PEOPLE HAVE SKILLS AND EXPERIENCE GAINED OVER THE PAST 20–30 YEARS FROM WORKING ON SUCH DIVERSE NAVAL SHIPBUILDING PROJECTS AS ANZAC FRIGATES, COLLINS SUBMARINES, MINEHUNTER VESSELS, ARMIDALE PATROL BOATS, AIR WARFARE DESTROYERS AND LANDING HELICOPTER DOCK SHIPS. GIVEN THE RIGHT CONDITIONS, THEY CAN CONTINUE TO BUILD THEIR SKILLS AND MAKE AUSTRALIA A WORLD-CLASS NAVAL SHIPBUILDING NATION.

The Future Submarine Industry Skills Plan is about Australia developing a national security asset. It is most certainly not about subsidising an industry. Companies skilled in building and maintaining equipment for the Australian Defence Force are a vital part of the Defence contribution to our security. Directly supporting Navy, a skilled naval shipbuilding industry is important to all the pillars described in *Australia's National Security Strategy*: countering terrorism, espionage and foreign interference; preserving border integrity; promoting a secure international environment; and the Australia–United States Alliance.

Recognising the importance of the naval shipbuilding industry, the Australian Government commissioned the Chief Executive Officer of the Defence Materiel Organisation to prepare The Future Submarine Industry Skills Plan. As it currently stands, the scheme of shipbuilding projects in the Defence Capability Plan creates gaps for the Australian shipbuilding industry with a decline in project activity that has already commenced and reaching its lowest point in about 2017. Depending on which projects will be selected for Australian build, this fall in the workforce could be quickly followed by a steep rise in activity around 2020. Such a cyclical pattern of work means skilled people will be lost to industry as work finishes, followed by a rapid rebuilding of capacity as the work returns. These peaks and troughs further deny industry the serious opportunity to invest, develop skills and improve performance over a longer period. This comes at a sizeable cost and with delays to projects as well as the erosion of productivity.

Without impacting the Australian Defence Force's capability, current naval shipbuilding plans can be adjusted to allow industry to develop world-class skills and consequently deliver warships to Navy on time, cheaper, and that meet the operational performance standards expected. National security remains the preeminent requirement, but shipbuilding plans can be optimised to provide industry with more predictable, better sequenced and longer term work, necessary foundations for business investment, productivity and performance improvement. For the Royal Australian Navy and the Defence Materiel Organisation, optimisation means early and better planned projects, with lower risk to execution founded on a partnership with industry. For Australia more broadly, optimisation means a small but proficient naval shipbuilding industry, performing at world benchmark levels and driving innovation in the advanced manufacturing sector of this nation. This does not mean that all ships must necessarily be built in this country: an optimised scheme may contain a combination of local and overseas build.

Work in support of this study and earlier work by the RAND Corporation and other organisations show that Australia possesses a number of skilled and experienced warship designers, with a good record in designing patrol boats and support ships. Against international competition, the WA company Austal designed the *Independence* variant of the US Navy Littoral Combat Ship. Submarines are the most complex warship to design and while Australia has some skilled people that can contribute to the design of a new submarine platform, we will need to partner with a proven submarine design organisation to meet this challenge. That organisation will contribute people to the design team and provide a proven framework of tools and processes.

Australia has good skills in the development and integration of combat and platform management systems. Australia has also developed world-leading skills in sub-systems development in areas such as electronic warfare and sonar. These skills have been built up over several decades, benefitting from the continuity of work and the challenge of successive projects. These skills should be preserved and developed to meet the challenges of the future submarine and other naval projects. One of the key steps to doing this is to ensure all major shipbuilding projects (current and future) have an embedded research and development component that works to steadily evolve the design baseline of successive ships. A permanent element of a rolling build program, directly connecting research and development to ship production, means costs, schedules and risks are controlled and innovative ideas have a practical and important destination.

Surveys and benchmarking of Australia's four main naval shipyards: ASC, Austal, BAE and Forgacs were part of a comprehensive analysis completed for this study. Along with a capacity assessment of the facilities in the shipyards, a capability assessment covered both production (structural fabrication, pipework, blast and paint, outfitting) and production engineering (shipyard build strategy, safety management, engineering, planning, procurement, materials handling, test and trials, quality control and administration). Shipyard productivity has also been assessed as part of an ongoing annual benchmarking program.

Our study has found that the shipyards have more than enough capacity in their facilities to build the warships planned, with the exception that some investment will be required to develop a suitable launch point for the very largest support vessels.

In terms of people, over the last five years the shipyards have grown the size of their workforce by several thousand people in support of the current shipbuilding projects. There are about 4,000 people now working for the four shipyards. While that number is at the sustainable level required for all future projects, experience levels are low overall. This is the result of the decline in shipbuilding in the mid-2000s. As a consequence, current productivity levels are low.

The impact of rebuilding from a low base for the current Air Warfare Destroyer and Landing Helicopter Dock ship projects was substantial and expensive. At the outset of these projects, the premiums in the prices tendered were considerable. This was the price difference between a cold start shipyard and a fully operational, proficient shipyard—not the difference between local or overseas locations. If Australian shipyards had the opportunity to build skills and experience and improve productivity, they too would offer lower prices. At Government Second Pass approval neither project could present a schedule that met the original delivery dates specified in Defence's capability plans. This cold start also caused problems for the projects as they were executed. This is typical of an industry in a rebuilding phase, and the impact can amount to billions of dollars for individual projects.

With the cost of all planned naval projects being somewhere above $75 billion, a proficient and productive shipbuilding industry would produce overall savings to the Defence budget in the tens of billions of dollars.

What is also evident from current projects is the substantial benefit of experience to a large, complex naval shipbuilding project. The benefit is not limited to better workforce productivity; other benefits accrue: initial project estimates are more accurate, risks are better understood and problems that cause additional cost and schedule blow outs are anticipated and avoided. The Air Warfare Destroyer project inherited the core of the combat system team that did the successful Collins submarine replacement combat system project. This experienced team has been able to execute their work on schedule and budget; and they had the knowledge and resilience to deal with problems as they emerged.

To meet the challenge of the future submarine and other naval projects, shipyard workforces will need to evolve to achieve the right balance of skill groups, strengthen skills and most importantly grow experience. Shipyard organisations will need to refine their engineering, planning and production processes and innovate to improve productivity. For Australia's shipyards, there is no fundamental impediment to achieving world–class performance. We must not be frightened of pursuing this objective.

Creating the opportunity to become a world–class naval shipbuilding nation depends upon Defence and industry working in true partnership to optimise the whole scheme of naval projects. The hallmark of improved Defence planning will be an integrated, long range plan for all naval shipbuilding projects that sets out practical plans for each project and balances inter–dependencies; it must be a plan developed in genuine consultation with industry; and a plan that is constantly managed and adjusted as circumstances change. Projects building an evolving series of ships are better than a set of short–run projects. Given that the run-down of certain workforce groups has already commenced, for example in areas of early project work like design and structural fabrication, quick action is required to retain key skills and experienced people.

With growing pressure on Government budgets, it is essential that industry also commit to better performance. Through investment, innovation and improved productivity, delivering cheaper warships is the dividend industry needs to deliver. The companies, unions and organisations represented on the Expert Industry Panel have all said they are prepared to make such a commitment.

Government, Defence and industry need to develop an itemised view on what naval shipbuilding capability needs to be developed in Australia. A diminishing number of warship suppliers in the global market, increasingly generic designs and the limited ability to buy the best technology means Australia should position itself to be more self–reliant in the design and manufacture of warships in the longer term. Complex warships like submarines and surface combatants need to be at the forefront of that plan.

Australia should use the next tranche of naval projects to further develop the skilled workforce that will take on the projects that lie beyond the future submarines. Our national security strategy must be supported by a detailed, practical and economical naval shipbuilding industry strategy. This will not be a large, expensive industry. In a national manufacturing industry of about one million people, shipbuilding will be a small, proficient and innovative industry founded on a workforce of about 5,000 skilled people.

RECOMMENDATIONS

The following set of recommendations draw upon all sections of this report. They are deliberately written as principles rather than a long list of specific tasks.

To build the skills to build the future submarines and the other warships required for the future fleet, the following actions are recommended.

1. Without adversely impacting the Australian Defence Force's capability, planning of the whole scheme of naval shipbuilding programs should be optimised to provide industry more predictable, better sequenced and long term work: the necessary foundations for innovation, business investment, productivity and performance improvement. This of course does not mean that all naval projects in the Defence Capability Plan will necessarily be built in Australia. Rather it means that naval shipbuilding projects should be planned with the aim of retaining wherever practical the current Australian workforce to place Defence and industry in the best position possible at the start of the next generation of projects. Defence and Government should take early action to ensure current workforce reductions are not causing the loss of skills important to future projects.
2. Defence should consolidate planning for all new warship programs into one group centred around the people managing today's projects so that genuine and current experience is applied. The initial schedule planning of naval projects for first entry into the Defence Capability Plan should be done by the Defence Materiel Organisation based on warship need dates and capability requirements provided by Chief of Capability Development Group and Chief of Navy.
3. The Defence Materiel Organisation should engage in more detailed discussion on a frequent and ongoing basis with organisations involved in naval shipbuilding, companies, unions and industry groups. No plan should be approved that is not broadly seen as being practical in terms of industry capability and capacity, schedule and budget.
4. Defence sponsorship of individual skills development schemes such as Skilling Australia's Defence Industry has been worthwhile for people involved in naval shipbuilding, particularly apprentices, and should continue. The Defence Materiel Organisation should develop and maintain a nationwide skills matrix based on matrices already used in the shipyards, extending to systems development, and use this to guide skills development sponsorship. Options to second select people to organisations with active submarine design and build programs should be investigated.
5. Industry should develop a clear plan to improve shipbuilding productivity in Australia, including setting specific targets, and commit to Defence and Government to delivering these dividends. Defence should continue to benchmark productivity on an annual basis.
6. Defence should structure the Future Submarine Program as a rolling build program, including establishing structured, funded and ongoing engineering and science and technology programs to deal progressively with equipment obsolescence and capability changes.
7. Defence should pursue the opportunity at the completion of the three ship Air Warfare Destroyer Program to flow key skills and expertise into the Future Frigate Program.

8. Working with industry and the Defence Science and Technology Organisation, the Defence Materiel Organisation should, as part of these programs, research the practicality and worth of a common architecture for Australian warship combat and platform management systems. This architecture would guide investment in technologies and products over the longer term.
9. Defence should re-examine the Offshore Combatant Vessel program to determine if technology and system readiness levels are sufficient for new types of equipment likely to be required to make the common platform solution technically viable and economical. Technical risk and other reasons might point to a better solution being to separate the patrol boat requirement from other requirements and consider separate projects.
10. The Department of Defence, through the Defence Materiel Organisation, should work with the Australian Customs and Border Protection Service and the Australian Antarctica Division of the Department of Sustainability, Environment, Water, Population and Communities to coordinate and optimise Australian Government shipbuilding programs.
11. Reflecting its worth in the development of this Plan, the Expert Industry Panel should be a part of the implementation process. As a guide, the panel might meet every three months for the first year and six monthly thereafter to provide views and feedback on the development of naval shipbuilding plans and preparations for the future submarine program.

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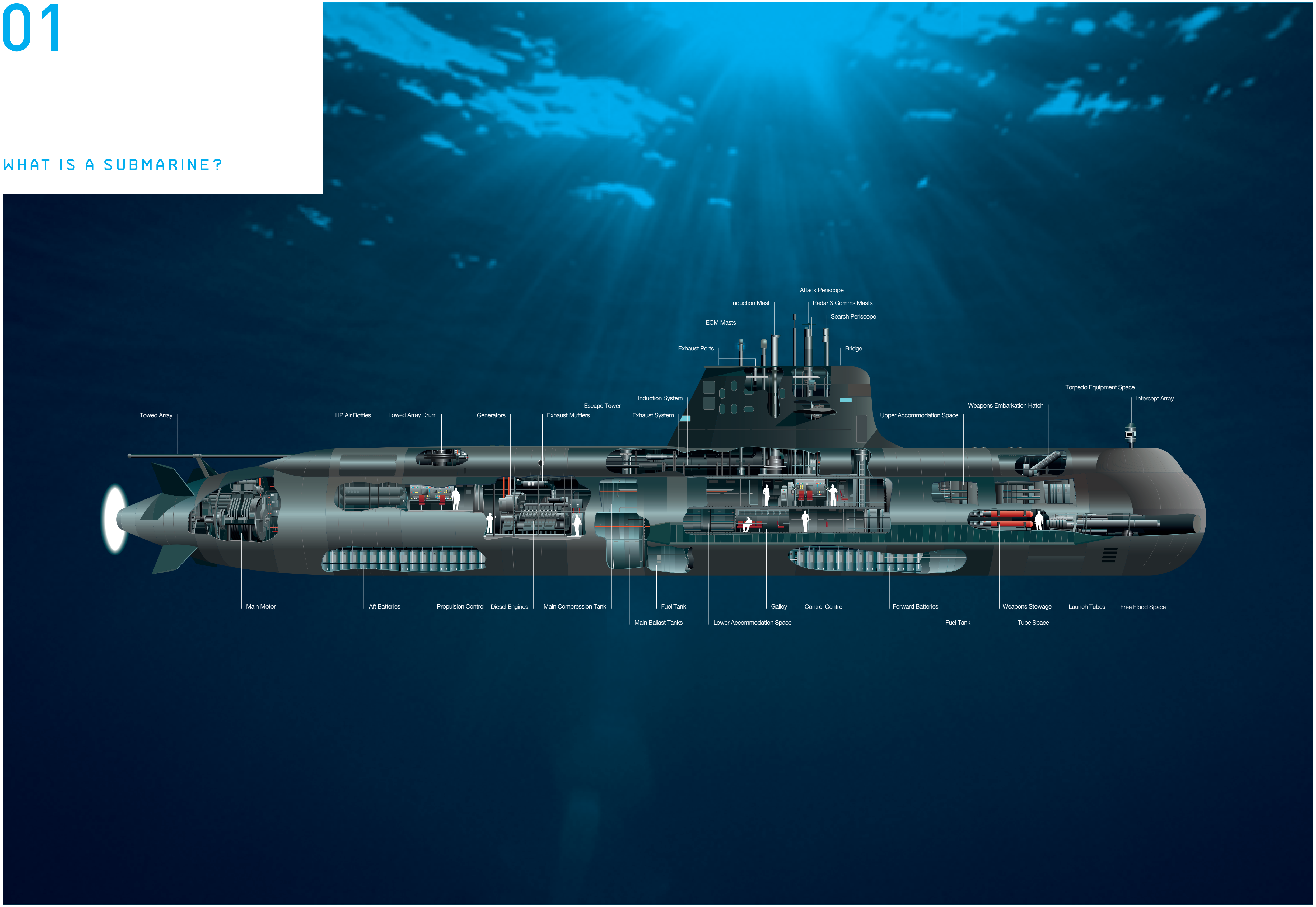
WHAT IS A SUBMARINE?



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WHAT IS A SUBMARINE?

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SUBMARINES ARE UNDERWATER WARSHIPS. THEY ARE DESIGNED TO OPERATE INDEPENDENTLY AT GREAT OCEAN DEPTHS AND REMAIN UNDETECTED FOR LONG PERIODS OF TIME. THEIR STEALTH IS THEIR DISTINGUISHING CHARACTERISTIC. AS THE ONLY TRULY COVERT MARITIME PLATFORM, SUBMARINES HAVE A DISTINCT ADVANTAGE OVER OTHER TYPES OF WARSHIPS AND ARE A SIGNIFICANT THREAT TO OPPOSING MILITARY FORCES. THIS ACTS AS A DETERRENT AND EXTENDS THE BENEFIT OF A SUBMARINE BEYOND JUST ITS OWN MILITARY FIREPOWER. FOR THIS REASON, THE SUBMARINE IS A CORE DEFENCE REQUIREMENT FOR MARITIME NATIONS.

The stealth, range and endurance of submarines allow them to access areas denied to other warships. Their roles include surveillance and intelligence gathering, surface strike, land strike, anti-submarine warfare, battle space preparation, support of special forces and offensive sea mining.

DESIGNING A SUBMARINE

Non-nuclear energy—typically diesel engines and batteries—power conventional, or so-called 'diesel-electric' submarines. These are one of the most complex of all military machines, with more parts and assemblies than both modern aircraft and modern surface ships. For example, there are over 70 systems in most conventional submarines. This high degree of complexity, coupled with the very difficult operating conditions, presents substantial challenges to submarine designers.

Most of a submarine's design is determined by its military capabilities and the nature of the intended missions. For example, the operational range will determine the quantity of fuel and other consumables, such as food, that are required. The level of machinery automation will influence the number of crew, the maximum dive depth will determine the strength of the vessel, and overall size will influence some of the submarine's stealth characteristics. No feature can be thought of in isolation. Each must be considered with how it interacts with other features in the overall design. Attempting to enhance a single feature will often detract from other performance characteristics.

It is essential therefore to determine the roles and capabilities of a submarine during the early stages of concept design. Submarines that operate over great ranges, such as the Australian fleet, are generally larger as greater submarine displacement is roughly proportional to greater operational range. Smaller submarines are limited in the number of weapons and sensors they can carry and have smaller crews capable of a narrower range of roles.

Larger submarines tend to have more sensors, weapons and bigger crews capable of managing multiple roles for several months. The Collins submarine, one of the largest conventional submarines in the world, displaces over 3,000 tonnes, has a crew of about 60 and can carry out multiple roles. A submarine of this type operates far from home in close proximity to an adversary's base or exercise areas. To enable this, designers aim to maximise range and endurance while taking into account the likely environments in which the submarines would operate. These include water temperature and sea states.

HULL AND HULL EQUIPMENT

A pressure hull, constructed of thick, high-strength steel, forms the primary barrier that protects the crew and equipment from the high pressures encountered when submerged. Hull sections at the bow and stern contain ballast and other water tanks, torpedo tubes and other structures that may be part of, or outside, the pressure hull. A casing sits on top of the pressure hull which is designed to reduce drag, turbulence and improve acoustic signatures and stealth. The overall shape of the hull is slender, generally cylindrical over the mid section and tapered at the rear. The casing includes a vertical structure, called the fin or sail, that houses communication equipment, periscopes and other devices.

The pressure hull has a number of compartments, and a watertight bulkhead separates each of these so that in an emergency a flood can be contained. The exact layout of the systems and equipment, pressure hull compartments, locations of bulkheads and other reinforcing structures is highly dependent on the flooding recovery and safety philosophy of the designer. Many iterations of the design are required to ensure harmony is achieved between space for equipment, strength of the hull, adequate range and minimal size to maintain stealth.

PROPULSION AND ENERGY SYSTEMS

The energy storage and propulsion system is what generates and stores the energy needed to service the submarine and propel it through the water. Conventional submarines use a hybrid diesel-electric propulsion and energy storage system. Diesel fuel stored in tanks is fed to generators that produce electricity to charge the main storage batteries. The energy from the batteries is then supplied to the main propulsion motor to propel the submarine (the 'propulsion load') and to all other electric equipment (the 'hotel load').

A diesel-electric submarine recharges its batteries every day or so by running its generators when the submarine is close to the surface, inducting air into the submarine via a 'snort' or 'snorkel' mast. At slow speeds the battery endurance is a number of days, but at the highest speeds, battery endurance may be as low as an hour.

A snorting submarine is more vulnerable to acoustic, thermal, radar or visual detection. Sensor systems are therefore at high alert while snorting, looking for early indication of any threat. If a threat is detected from an aircraft, ship or another submarine, the diesel-electric submarine immediately stops snorting and manoeuvres to avoid detection.

Some conventional submarines use air independent propulsion (AIP) systems as a secondary method of generating electricity. The benefit of AIP is that it avoids the use of diesel engines and enables the submarine to sustain low-speed patrol operations (typically for one or two weeks). AIP helps a submarine maintain stealth when operating in a high-threat environment where snorting would pose an unacceptable risk of detection.

SIGNATURE CONTROL SYSTEMS

Some designers maintain that smaller submarines are more difficult to detect, and so produce very compact and dense designs. Other designers, such as those for the Collins class, use greater volume to provide higher shock clearances to allow noisy equipment to be isolated. However the submarine can still leave detectable trails—acoustic, thermal and magnetic. For a submarine to mask its presence, it must be capable of reducing or eliminating these.

To do this, passive and active controls may be implemented onboard the submarine. Sound absorbing tiles on the hull reduce the chance of detection by enemy sonar systems and torpedoes. A degaussing system, which consists of electrically charged coils distributed over the entire length of the submarine, minimises the magnetic field produced by the metal hull. Radar absorbing materials are also used on submarine masts to reduce their radar signature.

WHAT IS A SUBMARINE?

Managing the emitted acoustic, magnetic, electrical and thermal signatures also influences the design of just about all systems and submarine components. For example, large rotating machinery (such as the diesel generators) is often mounted on isolation rafts to reduce vibration and help prevent sound passing through the hull into the water. External components of the submarine, including the hull, casings, rudder and propeller, are designed for hydrodynamic efficiency that reduces the noise of water flow emitted by these.

The extent to which coatings and materials (anechoic, radar absorbing materials, drag reduction, infrared and visual) are used to minimise detection far exceeds that used for surface combatants, and submarine designers go to extremes to minimise radiated noise and shock vulnerability .

ELECTRICAL SYSTEMS

Some installed equipment, such as compressors and pumps, need high direct current voltages which are supplied directly from the main storage battery through breakers and switchboards. Other equipment, such as lighting and ventilation fans, need lower voltages. Electronic equipment such as communications and combat system hardware even need lower voltages and multiple frequencies.

The power distribution system consists of cables, circuit breakers and switchgear. It connects the main storage batteries through power conversion equipment (commonly solid state devices, rather than rotating machinery) to the installed equipment.

COMBAT AND WEAPONS SYSTEMS

Submarines were originally designed to destroy ships by firing straight-running torpedoes. Their role was expanded to include anti-submarine warfare as the capability to detect other submarines and engage them with guided torpedoes was developed. Although many advances have been made since their early designs, dual-purpose (anti-submarine and anti-surface) guided torpedoes are still the primary element of a conventional submarine's weapon system.

Current weapons systems also include missiles for land and maritime strike as well as an emerging capability for air defence, mines to block foreign ports or military shipping routes, counter-measures to confuse and draw enemy sensors and weapons, underwater vehicles to help deploy special forces, and surveillance sensors and high speed torpedoes to launch rapid strikes.

A tactical control system (or combat management system) draws data from ship sensors and weapons as well as external data links to produce an overall picture for the submarine command team. The system also generates solutions to launch and guide weapons to their targets.

The weapons system also includes the complex machinery required to store, load and launch—or to position and recover—weapons and vehicles. These supporting systems enable weapons to be deployed fast, lengthy docking times to be avoided and also reduce the dangers of handling weapons.

SENSING AND COMMUNICATION SYSTEMS

All submarines have a range of onboard sensors that can be used in either active or passive modes. On a modern conventional submarine, the range of sensing and communication systems available includes periscopes and photonic sensors on non-penetrating masts, passive and active sonar, electronic warfare, navigation, communications and radar systems. Periscopes and photonic masts can operate in daylight, infrared and lowlight modes, and enable the operator to search, detect and identify air and surface contacts and threats. High data rate communications are increasingly important in a networked military force. The need to maintain stealth dominates sensor employment, so generally active modes are avoided.

The passive sonar system is the most important submarine sensor. Sonar operates at all times when a submarine is dived to detect, track and classify contacts and threats by passively listening to their emitted noise signatures. An active sonar system on the other hand, transmits a pulse of sound and then identifies the presence of objects by listening for the reflected sound. Active sonar is used to detect obstacles and manoeuvre safely in shallow waters.

The navigation system allows the submarine to conduct a mission safely using a combination of inertial navigation units (compasses), logs (speed measurement), depth meters, echo sounders and global positioning system (GPS) receivers. GPS relies on an antenna being exposed above water.

MANOEUVRING

A submarine must be agile and highly manoeuvrable. It must be able to accelerate quickly, turn rapidly, change depth swiftly and increase speeds while remaining as quiet as possible. Such capabilities are a result of numerous design features, including the location and configuration of the control surfaces as well as the entire hull. Control surfaces are mounted aft (rudders) and forward. The aft control surfaces are usually mounted in a cruciform (+) configuration ahead of the propeller, but some submarines have X-form rudders that enhance manoeuvrability. Forward control surfaces can be mounted either on the fin or the forward casing and are generally disconnected at high speed.

Conventional submarines are fitted with propellers, rather than propulsors, for efficiency, noise and weight reasons.

Surfaced submarines can stay on the surface because their ballast tanks are empty, providing positive buoyancy. To dive, the submarine's ballast tanks are flooded with seawater. To surface, the seawater is blown out with compressed air while the submarine is moving through the water with the control surfaces in a down or rise attitude. Conventional submarine ballast tanks are usually located externally to the pressure hull, generally on the bow and stern sections.

The ballast tank volume is normally around 10 per cent of the dived displacement, so a modern submarine's reserve buoyancy is low—only one tenth of its displacement would need to flood before it could no longer surface. Some submarines have emergency systems which enable the ballast tanks to be blown quickly. This produces a rapid gain in positive buoyancy and allows the vessel to surface before flooding exceeds the reserve buoyancy.

A submerged submarine must be maintained in neutral buoyancy so it does not need to use speed to maintain its depth. Weight compensating and trim tanks are fitted throughout to allow for changes due to hull compression, water density, fuel use and weapon launch. These systems enable a submarine to maintain depth with the least amount of energy, which is especially important for a conventional submarine. A submarine that is 'out of trim' can maintain its depth by increasing speed so that its control surfaces have more effect, but this detracts from the vessel's stealth. A submarine that is 'in trim' can slow down or stop to avoid detection without losing control of its depth.

HUMAN FACTORS

Crew effectiveness is integral to operating a submarine successfully, so it is critical that the vessel's living and operating conditions support the crew and its peak performance for long periods. The submarine environment is different to any other workplace. It is surrounded by water and has no contact with the atmosphere, except while snorting. A submarine also often needs to be entirely independent for the duration of a mission, so it must have good accommodation, food storage spaces, and messing and recreation facilities.

Crew endurance is directly related to the size of the submarine. Small crews have limited capacity to absorb the stresses caused by prolonged operations in intense threat environments, the need to repair defective equipment or to react to a change in objectives. Larger crews are better able to absorb these changes and so are likely to be more effective on longer patrols.

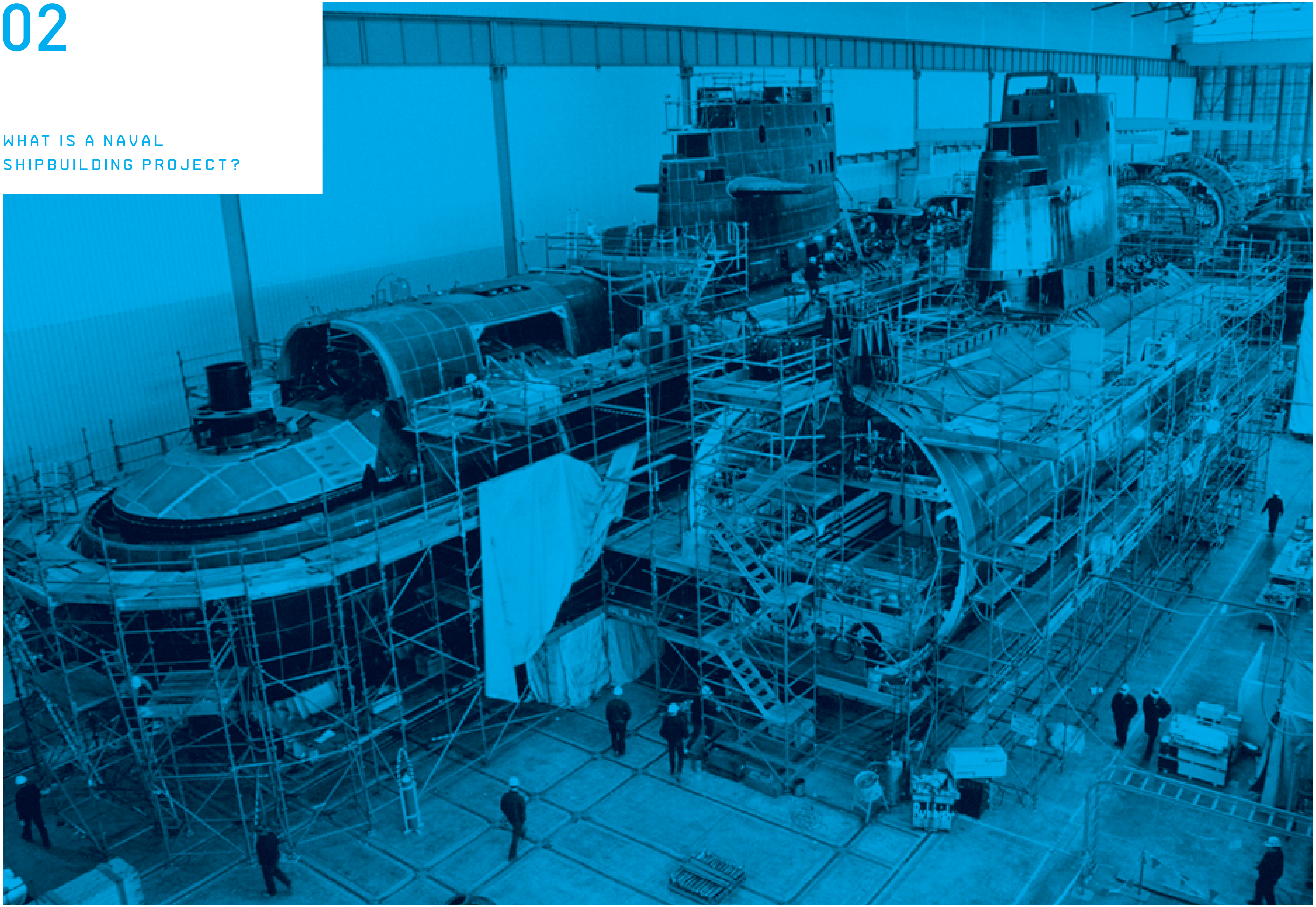
Life support systems are essential for the wellbeing and safety of the crew. All modern conventional submarines have some mechanism for generating oxygen, removing carbon dioxide and providing drinking water. Heating and cooling systems control the temperature of the air, and the humidity is closely monitored and maintained throughout the duration of a patrol. If there is a fire or air is contaminated, there is a readily accessible supply of emergency breathing air.

SUMMARY

The conventional submarine's wide-ranging roles, flexibility and robust construction all combine to produce a unique combat machine. Stealth remains paramount to covert underwater operations and will remain the submarine's primary advantage. The high degree of complexity, coupled with unique and difficult operating conditions, present major challenges for submarine designers.

02

WHAT IS A NAVAL SHIPBUILDING PROJECT?



WHAT IS A NAVAL SHIPBUILDING PROJECT?

A NAVAL SHIPBUILDING PROJECT INVOLVES THOUSANDS OF PEOPLE, BILLIONS OF DOLLARS AND RUNS FOR ABOUT A DECADE IF NOT LONGER. THEY ARE COMPLEX ENGINEERING ENTERPRISES THAT DEAL WITH THE MOST ADVANCED TECHNOLOGY AND SOPHISTICATED ENGINEERING DESIGNS, ALL THE WAY THROUGH TO TRADITIONAL HEAVY INDUSTRIAL ACTIVITY. NAVAL SHIPBUILDING PROJECTS HAVE BEEN SOME OF THE BIGGEST ENGINEERING ENDEAVOURS UNDERTAKEN IN AUSTRALIA, AND ARE OFTEN REFERRED TO AS NATION BUILDING. WHILE THIS MAY BE A BOLD CLAIM, THEY ARE CERTAINLY AT THE CENTRE OF AUSTRALIA'S ADVANCED MANUFACTURING INDUSTRY.

This section gives an overview of a naval shipbuilding project and aims to provide a sense of what is involved in their execution. Some of the activities described will be familiar, but much of the work is largely hidden to outsiders and very often critical to the success of these projects.

PROJECT STAGES

A typical naval shipbuilding project can be characterised as having four main stages: design, production engineering, production, test and activation. Operation and sustainment of the ships follow after these stages. While there are many different ways to break down a shipbuilding project, the following provides a summary.

The skills and activities in each stage are:

- Design—from a set of top-level customer requirements, this stage involves engineers and draftsmen creating the warship's engineering design, which covers all the systems described in section 1 of the report. This includes the hull, propulsion, weapons, combat management system and communications. A key product from this stage will be a computer model of the ship from which two and three dimensional drawings and specifications can be extracted.
- Production engineering—this is the term used to describe the engineering and other activities required to take the static design of the warship and generate the information required to build it. Specialist engineering designers and experienced shipbuilders do the work of building the ship. Other professionals, such as project managers, safety managers, human resources staff, warehouse managers, purchasing officers and many others, set up and operate a shipyard. Outcomes of this stage include a detailed build strategy, usually involving modular construction and sometimes two or more block manufacturing shipyards. Once the build strategy has been decided, detailed work orders will then be written for each and every task to be completed, bills of material created, contracts with hundreds of suppliers drawn up and signed, extensive and complex schedules of work developed, inspection and test procedures written for all aspects of construction, workforce management plans and financial control systems put in place.
- Production—this is the face of shipbuilding that most people recognise. It has thousands of skilled trades people cutting and welding steel, installing pipes, electrical cable and ventilation trunking. These people work for years to build something so large it is on a scale rarely seen in industrial manufacturing. As well as welders and electricians, production also involves technicians installing computer systems, radar systems, missile launchers, large gunmounts, gas turbines, propulsion shafting and propellers. Most of this work takes place in large build halls at the shipyards. As the shipbuilding project progresses, however, and the blocks are brought out for consolidation, it is easy for those outside the shipyard to see these massive steel structures and masts that will eventually form the familiar shape of a warship.
- Test and activation—as the ship is assembled and equipment installed, groups of specialist technicians come on board to check the installation, set to work equipment and put it through an extensive and rigorous range of tests to ensure it functions correctly. This is not the first time testing has happened. Before installation onboard the ship, testing is undertaken on the factory floor to ensure each piece of equipment performs according to specification. Sometimes there will be problems and the technicians will need to fix problems such as incorrect cable connections, misalignment of machinery, and defective components. This work covers moderately simple equipment such as freshwater pumps, all the way through to the very precise alignment of the main propulsion train and weapon systems. Once the equipment has been set to work correctly, the next step is to conduct thousands of tests to prove that each piece of equipment, both on its own and when integrated with other systems, performs to the design and contract specifications.

Most people believe shipbuilding is simply design and construction. What is not so widely recognised and understood is the need for production engineering and test and activation that accompanies the other stages. Production engineering is critical: it is a highly skilled engineering and construction control activity and the success of a naval shipbuilding project depends on getting this right. Poor production engineering will result in poor shipyard productivity, budget overruns and late delivery, as well as poor quality work and ultimately a defective ship that might not be fit for purpose.

Similarly, the test and activation stage involves specialist skills. While design and production can rest on foundation trade and engineering skills, production engineering and test and activation are highly dependent on genuine and current expertise which comes from experience and a deep understanding of the whole shipbuilding endeavour. The rigour involved in testing warships aligns with the complexity of their military role. Thousands of operational requirements have to be precisely tested in very specific conditions, often harsh, to ensure that every piece of equipment, separately and together, will function as expected when the ship is in combat.

The four stages described above are not run separately or in isolation from each other. Production engineering work will (or should) start at the same time as functional design and continues through the production and test and activation stages of the project. For example, as the designers are sketching out the structure of the ship, the production engineers will be identifying where the block breaks will occur to enable the ship to be fabricated using the modern method of block construction. They will suggest ways for the designers to make it easier to build the ship. As equipment is designed, specified and manufactured, experts in test and trials will be extracting information to plan their trials as well as providing input to the designers to make testing easier. Well before production commences, experts at the shipyard will be assessing the design to determine requirements including trade skills, workforce numbers, recruiting and training needs, infrastructure upgrades and warehousing.

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WHAT IS A NAVAL SHIPBUILDING PROJECT?

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SYSTEMS ENGINEERING

Warships are very complex machines. In fact submarines are more complex than almost all other man made machines, and are on par with the space shuttle. As technology advances and operational requirements increase, warships are becoming ever more sophisticated and there is no end in sight to this advance. Systems engineering is a discipline developed over past decades that involves a top down, structured approach to the design, development and construction of highly complex machines that must meet a challenging set of customer requirements.

The systems engineering process is the thread that runs for the entire duration of a naval shipbuilding project to ensure that what is delivered meets the customer's performance specification. The simplest depiction of this very sophisticated process is shown below, the classic systems engineering 'V diagram'. The V represents the idea that requirements are translated into the construction of the system, say a warship, and then proven through a series of tests to meet the customer's requirement.

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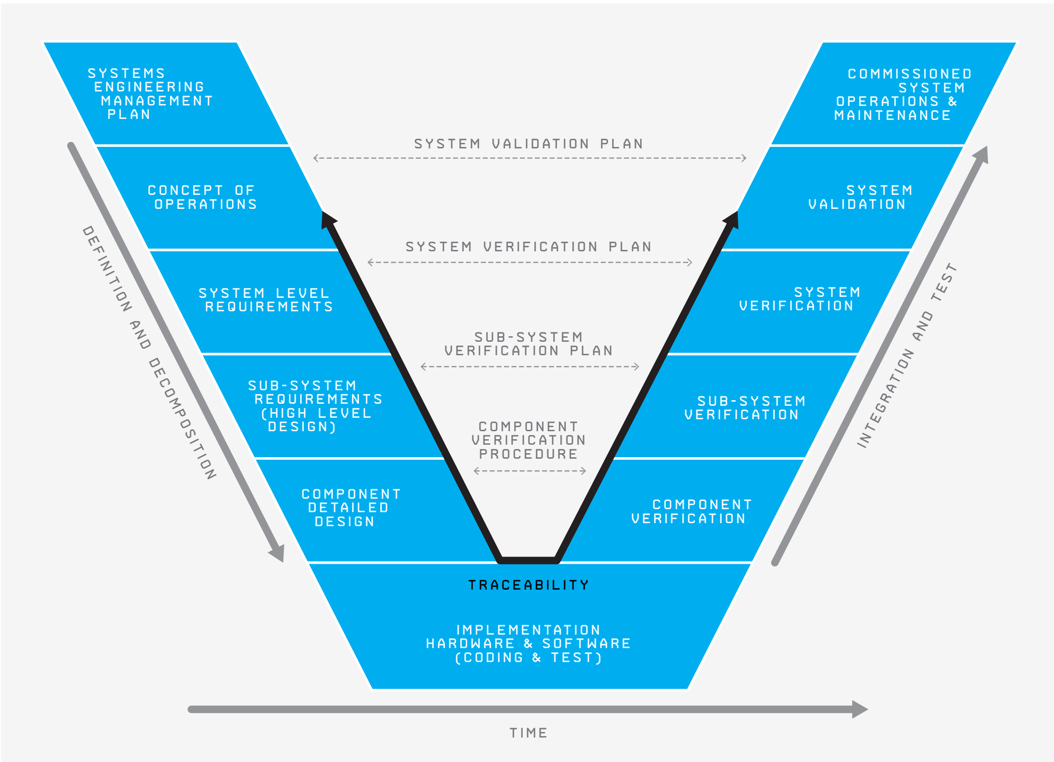
FIGURE 2.1: SYSTEMS ENGINEERING 'V' DIAGRAM



For a submarine or a destroyer, the top level requirement set will typically number in the order of 10,000 distinct requirements. Following a disciplined systems engineering process, designers produce a functional architecture that allocates each requirement to a system, and then design that system to satisfy all allocated requirements. Ensuring the warship meets all requirements, and that the design of equipment is harmonised so that it all fits inside the ship, is an incredibly challenging task and one that typically involves thousands of skilled people over many years.

TYPICAL PROJECT SCHEDULES

Construction projects for the ten ANZAC class frigates and six Collins submarines both ran for about 20 years, while the project to build three Air Warfare Destroyers will run for about 15 years. This is typical of major warship projects. Building smaller or simpler ships does not take as long. The Armidale Patrol Boat project, which provided 14 boats for the Royal Australian Navy, ran for about five years, and the two ship Landing Helicopter Dock project will run for about eight years. Inside Defence, planning for these programs extends several more years.

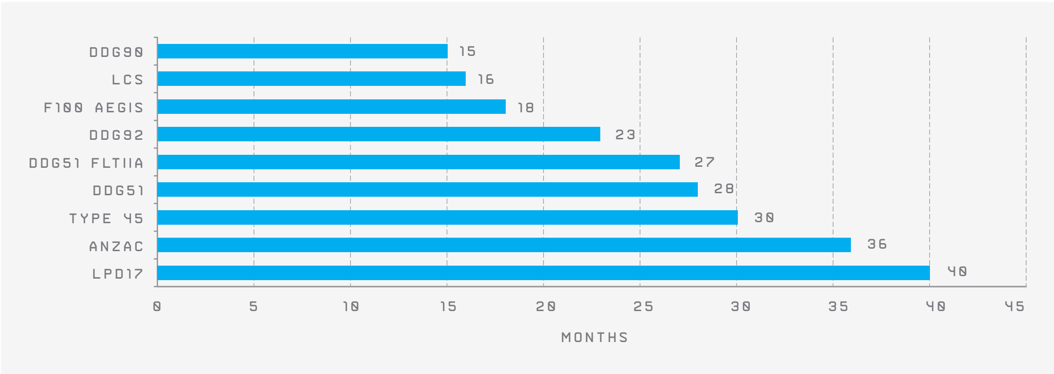
Typically in Australia, major warship projects involve purchasing an existing platform design and core combat system. The Collins submarine and Air Warfare Destroyer projects started with an existing platform design and existing core combat system. A considerable amount of design and development went into adapting these designs to Australian requirements, but none of these projects involved a design from first principles.

An experienced competent design house will take many years to produce a detailed, functional design for a destroyer or submarine. Research and analysis specialist RAND has measured the duration of a new design from the start of concept to delivery of the first of the new class. The duration depends on the complexity of the requirement, any schedule and budgetary constraints, and the skill and proficiency of the design workforce. As a benchmark for the design duration, the US Navy's Ohio, Seawolf, and Virginia class designs took approximately 15 years taken from the start of the conceptual design to the delivery of the first boat (RAND MG-608, pg 30). The level of effort was an estimated 35 million work hours for the Virginia class design.

To provide a basic measure of the time involved in production engineering and production, two periods are quoted: time from preliminary design review to start of construction, and duration of construction for each ship. The following diagrams show those schedules for a range of international warship projects. As an indication, it takes about two years from late in the design process to the start of production. This varies depending on the number of designers and draftsmen that can be applied to the task. This doesn't mean all production engineering is completed in two years —just enough is done to start production work. For a surface ship, the designer and shipyard will typically concentrate on the keel blocks as the priority. For a submarine, this period is usually longer than for a warship and production would typically start on the central blocks (or 'rings'). For the Air Warfare Destroyer project, production started a little more than two years after the Spanish F-100 platform design was selected (at Government Second Pass), noting the project had been assessing the design for construction in Australia for over a year before that final decision.

WHAT IS A NAVAL SHIPBUILDING PROJECT?

FIGURE 2.2: WARSHIPS: PRELIMINARY DESIGN REVIEW TO START OF CONSTRUCTION



In terms of production duration, which includes test and activation and all other pre-delivery activities, the typical period for a complex warship is about five years. The first of class takes longer than the subsequent ships. In its DDG-51 destroyer program of more than 60 ships, the US Navy experienced noticeably shorter and longer build periods, and generally settled on a period of about five years being optimum in its shipyards' circumstances. Given that the Air Warfare Destroyer project commenced from a cold start that resulted in problems with early production, the build duration for the first Air Warfare Destroyer has grown from five to six years.

FIGURE 2.3: WARSHIPS: START OF CONSTRUCTION TO DELIVERY

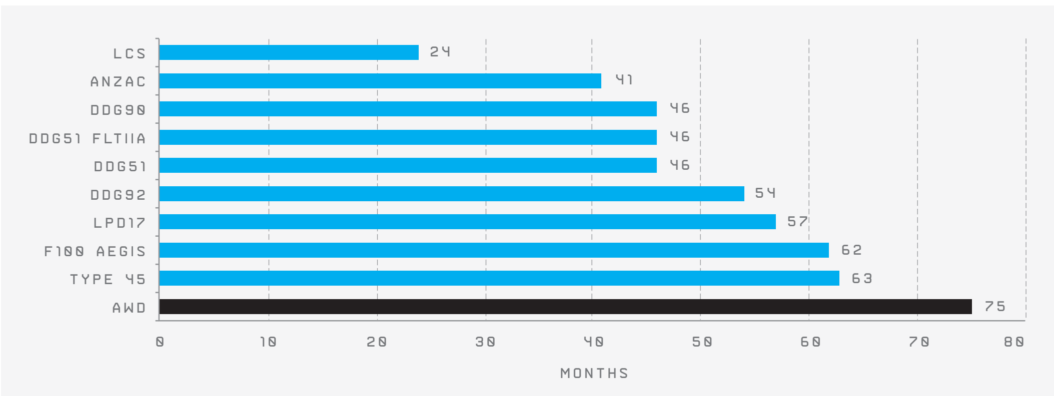
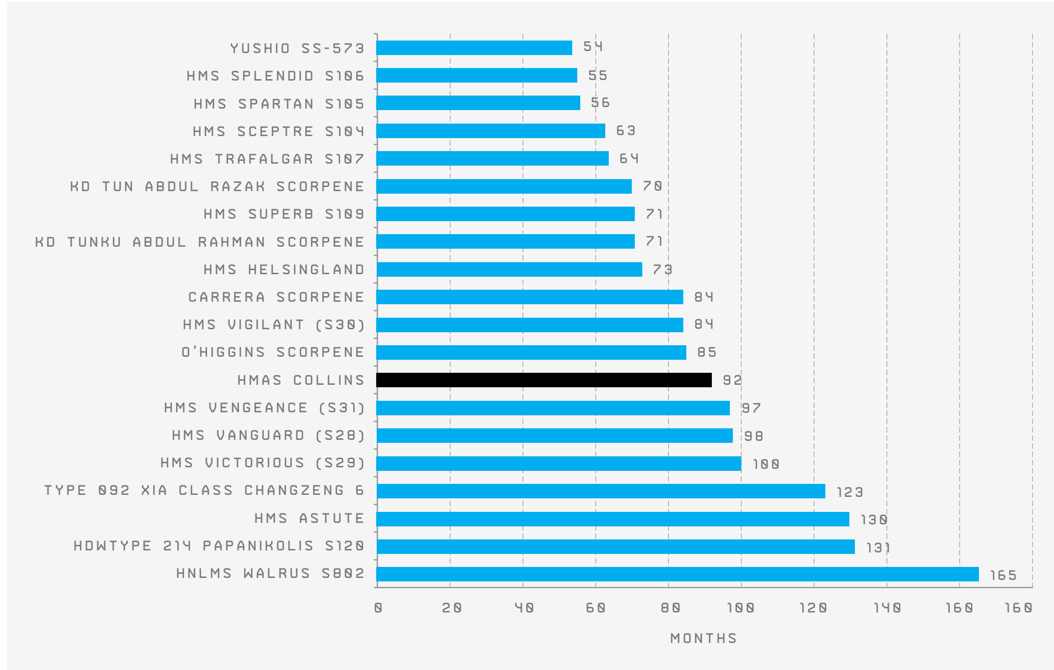


FIGURE 2.4: SUBMARINES: START OF CONSTRUCTION TO DELIVERY



For submarine programs such as the US Navy's Virginia class, build duration is typically 60 months. The first Collins class submarine took 92 months from steel first being cut to delivery.

TYPICAL PROJECT BUDGETS

According to published figures, the Air Warfare Destroyer project will cost about $8 billion, and the Landing Helicopter Dock projects about $3 billion. The ANZAC ship and Collins submarine projects are often quoted as costing $5 billion, which in today's dollars would be about $9 billion.

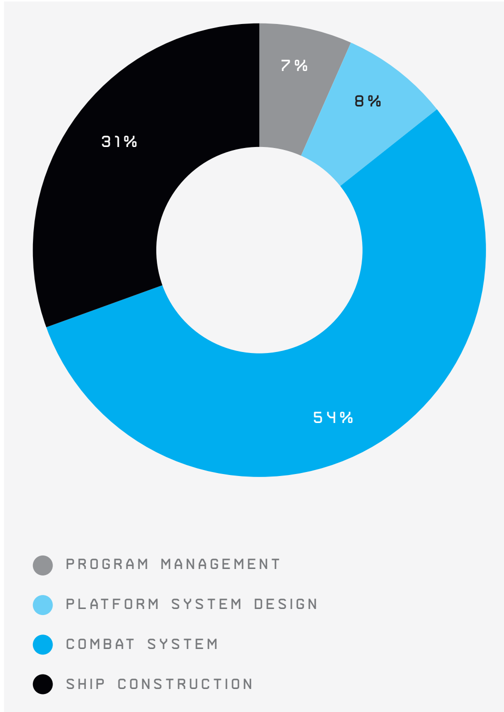
Establishing comprehensive data on the cost of warships built overseas is difficult: it is closely guarded, inflation and exchange rate changes are often left out, and the scope included in many publicly announced prices is never made clear. The Defence Materiel Organisation has published an analysis of the cost of ships and submarines, and their trend over time. Other agencies have done similar work. The trend in warship prices is that they are increasing at about twice the rate of inflation because of their growing complexity.

WHAT IS A NAVAL SHIPBUILDING PROJECT?

The overall cost of a naval shipbuilding project depends on a multitude of factors, the obvious ones being the number of ships required, whether the project includes a new design or uses an existing design, and the complexity of the ships. Size or displacement of the vessel is not a linear indicator of cost. An old rule used to be the cost to design a warship used to be about equal to the production cost of one ship. So for a four ship program, 20 per cent of the project budget would be spent on non-recurring engineering. Clearly, the more ships, the lower the overhead will be on each one. This ratio for design seems to be increasing—not just in quantum but proportionally as ships become more sophisticated. The number and complexity of systems and their many interfaces is increasing, and it is taking more engineering effort to design in proportion to the cost of each piece of equipment. For the most sophisticated submarines and destroyers where system count and density is high, indications are that the non-recurring engineering proportion might now be equivalent to two or more ships.

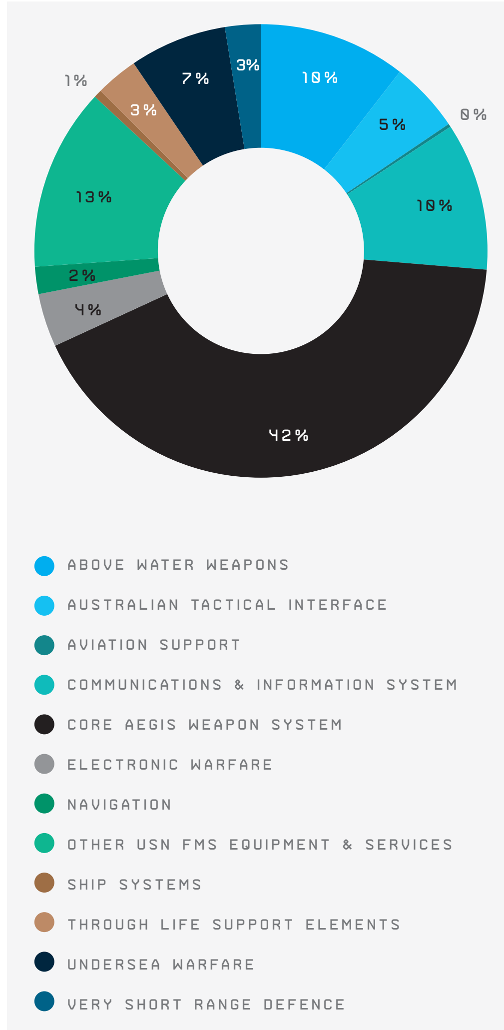
To illustrate a typical budget of a major warship project, the following diagrams show different levels of budget breakdown for the Air Warfare Destroyer project. Within the two major groups of combat system and ship construction, there are labour and equipment costs that extend beyond the prime contractors right through the many tiers of the supply chain. The first diagram illustrates a typical split for a warship project based on an existing platform design and demanding operational requirements of the combat system. Design services are still required for the platform to integrate a new combat system. The effort to construct a ship is dependent on the volume of the ship and the complexity of its design. Split another way, the budget roughly divides into 50 per cent for labour and 50 per cent for materials and equipment.

FIGURE 2.5: AIR WARFARE DESTROYER BUDGET BREAKDOWN



The cost of the combat system depends on the operational, functional and performance specification. For the Air Warfare Destroyer, the operational requirements reflected its sea control combatant role with a complete range of very demanding sub-system requirements. It also included the development of the Australian Tactical Interface, which interfaces Australian selected equipment to the core Aegis combat management system. The following diagram illustrates the breakdown of the combat system budget by sub-system.

FIGURE 2.6: AIR WARFARE DESTROYER COMBAT SYSTEM BUDGET BREAKDOWN



TYPICAL PROJECT WORKFORCE

Today, the Air Warfare Destroyer project has a direct workforce of around 1,800 people who work for ASC, Raytheon Australia and Defence. They include engineers, accountants, business managers, safety officers, human resource managers, logistics specialists, warehouse experts, welders, electricians, painters and crane operators. They are primarily based in Adelaide and Sydney, with small numbers in Melbourne and Newcastle as well as in the United Kingdom and United States.

Extensive research by Tasman Asia Pacific into the ANZAC ship project determined that in 1994–95, approximately 2,560 people were directly employed by Tenix and its sub-contractors to produce ten ANZAC frigates. Of these, some 1,223 were employed directly by the prime contractor, Tenix on the project (Tasman 2001, p.78).

Similar research on the Mine Hunter Coastal project determined that over nine years, the project generated or sustained an average of more than 1,800 full-time equivalent jobs each year. The Mine Hunter Coastal project in Newcastle built six Huon class ships from 1994 to 2003 that were 52 metres long and weighed about 700 tonnes. The hull of the first ship was manufactured in Italy, but fitted out in Newcastle.

In 2005, there were only a handful of people working on the Air Warfare Destroyer project before it was decided to set up the headquarters for the project at the Air Warfare Destroyer Systems Centre in Adelaide. Since then, a new ASC shipyard and adjacent Government of South Australia's Common User Facility have been built which represent an investment of about $500 million in shipbuilding facilities. There are now about 800 white collar workers in the systems centre and shipyard, as well as about 700 blue collar workers and apprentices.

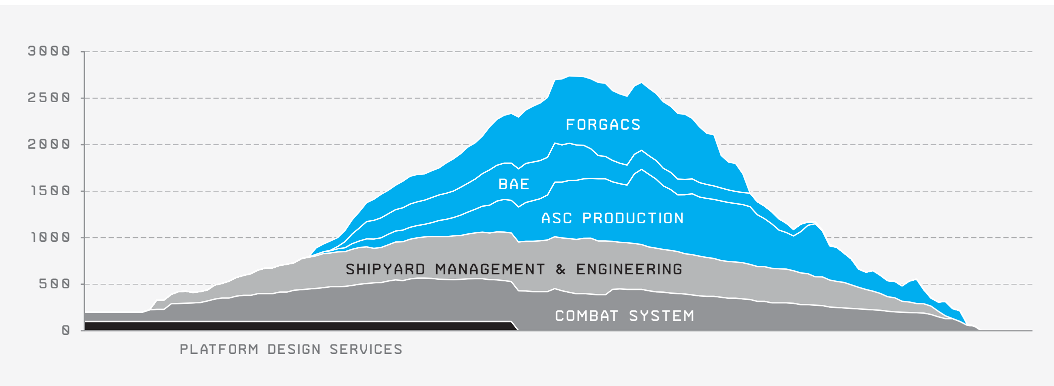
WHAT IS A NAVAL SHIPBUILDING PROJECT?

Beyond the three principal organisations involved in the Air Warfare Destroyer project (ASC as lead shipbuilder, Raytheon Australia as the combat system integrator and Defence Materiel Organisation), there is a multitude of subcontractors whose workforce also numbers in the thousands. Large sub-contractors include Forgacs, which at its shipyard in Newcastle has about 750 workers, and BAE Systems, which has at its shipyard in Melbourne a workforce of around 200 manufacturing Air Warfare Destroyer hull blocks. Other organisations contribute skilled workers to the project in the supply of major off-the-shelf systems such as Lockheed Martin who design and construct the core Aegis combat system.

The workforce growth profile for the Air Warfare Destroyer program is shown in the following diagram. It includes all three shipyards: ASC, BAE Systems and Forgacs. The graph shows a typical workforce build up profile, and emphasises combat system and production engineering functions at the beginning before the production workforce grows. Notable is the continuation of this engineering support throughout the project.

As mentioned, not everyone working on a shipbuilding project is an engineer or welder. Of the 1,000 people in the Air Warfare Destroyer non-production workforce, on average only 30 per cent are engineers, with the proportion being higher in the combat system team as compared to ship construction. In the Adelaide production workforce of about 650 people, about 100 are scaffolders, crane operators, stores workers and trades assistants. This shows that major naval shipbuilding projects involve people with a wide range of skills, many of which are not unique to shipbuilding. In terms of building teams for projects like the future submarine, many of the skilled workers can come from other industry sectors.

FIGURE 2.7: AIR WARFARE DESTROYER WORKFORCE BREAKDOWN



SUMMARY

Modern warships are complex. Submarines are some of the most complex machines ever built. Projects to build such machines can be split into four main phases: design, production engineering, production, and test and evaluation of the completed vessel. They require a workforce with wide ranging skills and can run for about 15 to 20 years. If an existing design is chosen for the project, it will take at least two or three years to adapt and develop it for Australian requirements. Producing a design from scratch will add years to the project. Beyond the design requirements, production schedules must take account of the time needed for production engineering, the majority of which can only start once the design is well developed.

The cost of naval projects is increasing as vessels become more complex, increasing at about twice the rate of inflation. The proportion of the project budget for design and non–recurring engineering is increasing as specifications become more demanding. For a submarine or destroyer, that work can cost two or more times the production cost of each vessel.

A typical shipbuilding project will employ thousands of people, including engineers and draftsmen who design the vessel and its systems, shipyard production engineers who break down the design into step-by-step work packs for trades people who use them to turn steel, pipes and electrical cables into a ship, the technicians who install its combat system and communications suite, computers and equipment, and the engineers and technicians who test the vessel once it is complete. There is the shipyard team who keep production running: schedulers, warehouse staff, the finance people, and the administrators. Throughout the project, it is the systems engineers who are tasked with making sure the ship meets the customer's requirements. There are many more who work in the supply chain that provides materials, equipment and services to the projects.

Large defence companies and small to medium enterprises employ those working on naval shipbuilding projects, and these jobs are located all around Australia. For some, it will be the first time they have helped build a warship, while for others, it this been their life's work for 30 years.

03

WHY WE NEED A PLAN

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WHY WE NEED A PLAN

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THIS SECTION EXAMINES KEY ISSUES THAT WILL AFFECT FUTURE PROJECT SUCCESS, INCLUDING LESSONS LEARNT FROM RECENT PROJECTS AND THE CURRENT PLAN FOR NAVAL SHIPBUILDING PROJECTS. AN ANALYSIS OF THE SKILLS CURRENTLY AVAILABLE IN THE SHIPBUILDING INDUSTRY AND DESCRIPTIONS OF THE SKILLS REQUIRED FOR THE FUTURE SUBMARINE PROJECT ARE PROVIDED IN FOLLOWING SECTIONS.

RECENT NAVAL SHIPBUILDING IN AUSTRALIA

In late 2009 when work started on manufacturing the steel hull blocks for the Air Warfare Destroyers, it had been many years since Australian shipyards had built a warship. In Melbourne, the BAE shipyard delivered its last ship in 2007—the *Canterbury*, a sealift and amphibious support vessel for the New Zealand navy. In Newcastle, Forgacs last undertook work on manufacturing blocks for the ANZAC ships in 1999, although it did complete a luxury yacht for a commercial customer in 2005. In Adelaide, ASC completed the last of the Collins class submarines, *Rankin*, in 2001.

This gap in work meant the Melbourne and Newcastle shipyards had each reduced to a workforce of about 100 people. During the ANZAC ship project, the shipyard prime and subcontractors had a peak workforce of over 1,600 people and Forgacs had a peak workforce of about 600.

In Adelaide, ASC retained from the Collins construction project a workforce of about 700 people to provide through life support and full cycle dockings for the submarines. The shipyard facilities required for Air Warfare Destroyer construction did not exist, so while ASC had experienced people in its submarine facility, and had moved some of these across to the Air Warfare Destroyer shipbuilding project, the company in effect had to establish a new workforce and a new shipyard.

At that time, a lot of skilled and experienced shipbuilders had left the industry. From 2007 when the Air Warfare Destroyer project was approved by government, ASC had to establish a project management and production-planning workforce. From 2009, all the shipyards had to build up a production engineering and production workforce.

The impact of this on the Air Warfare Destroyer project was that production capacity could not be increased as quickly as planned. The lack of experienced shipbuilders also meant productivity was low and mistakes were made. To an experienced shipbuilder, the result was predictable. Various experts who reviewed the project commented that the problem was not unusual and that similar situations had been experienced elsewhere.

The problem was not an inability to recruit a trade workforce—trade recruiting has generally gone to plan—but rather building up the expertise and capacity of production engineering organisations, and a shortage of experienced workshop engineers and supervisors.

In relation to the first issue, the project team across all the shipyards could not generate production work packages—documentation and material—quickly enough to feed the production operation. There were several causes for this:

- the time needed to complete the Australian modifications to the detailed design of the Spanish F-100 platform
- a limited number of people experienced in developing build strategies, detailed plans and schedules
- lack of capacity to process the volume of documentation in all the production work packages

The lack of experienced workshop engineers and shipyard supervisors also affected the project. The problems with early block manufacturing across all the shipyards were symptomatic of inexperience, and action by all companies to attract and recruit more experienced supervisors resulted in immediate improvements.

What is also clear is that if these issues had not been faced and resolved in Air Warfare Destroyer block fabrication, the very same problems would have affected the manufacture of Landing Helicopter Dock blocks in Australia and caused delay in delivery of those ships.

Today, across the three shipyards there is a production workforce of about 1,800, which is supported by a production engineering organisation of about 1,000 people. The problems seen two years ago are gone, people have learnt from the experience and are dealing with the challenges of block fabrication as part of their normal routine. Having gained the basic skills, the next objective is to improve productivity. This will take practice and time.

RECENT COMBAT SYSTEMS DEVELOPMENT IN AUSTRALIA

In contrast to the shipyard situation, when systems development began on the Air Warfare Destroyer project in 2005, a lot of development work was still underway on the replacement combat system for Collins class submarines, which was being led by Raytheon Australia. Work on the ANZAC class combat system led by Saab Systems was in a sustainment mode, which involves a level of development, but not the peak activity and workforce required in the primary development stage.

The combat system architecture for the Air Warfare Destroyer was approved in 2004 based on a core Aegis combat system from the US Navy. Raytheon Australia was selected as the Air Warfare Destroyer combat system integrator in 2005. This allowed Raytheon to transition their core team that had been working on the Collins submarine replacement combat system to the Air Warfare Destroyer combat system. The benefit of having an experienced team at the beginning of the AWD project was enormous.

The advantage of capturing an existing team is not just that a certain number of experienced people can be easily recruited. A far greater benefit is the established processes and dynamic team work that is obtained. The engineering task of developing and integrating a new combat system, even from an existing core like Aegis, is considerable. What the Air Warfare Destroyer experience showed was that speed and efficiency can be achieved with a proven team. If the task had been undertaken by a new team, it would have required many more people because of low productivity, considerable investment in new tools and process, time to prove and tailor all those tools and processes, and time for the team to work out roles and dependencies. Most of all, the team would not be anticipating and avoiding problems.

From a core of about 50 people, and backed by the tools and processes of a global company, the Air Warfare Destroyer project has built a team of about 400 to work on the combat system, to integrate the system into the platform, and to manage overall project planning and control. The project did not miss any design reviews scheduled for its first three years (system design, preliminary design and critical design). This is almost entirely because the task was started by an experienced, proven team.

WHY WE NEED A PLAN

DEFENCE CAPABILITY PLAN

Two major naval shipbuilding projects are currently underway in Australia: three Air Warfare Destroyers and two Landing Helicopter Dock ships. While not strictly a naval project, Austal are also constructing eight Cape Class patrol boats for Australian Customs. The 2009 Defence White Paper also defined a fleet of 48 new warships to be acquired over the next 20 years as part of Force 2030: 12 submarines, eight frigates, up to 20 multi-mission offshore combatant vessels, six heavy landing craft, one strategic sealift ship and a replenishment and logistics support ship.

As well as its submarine component, the Royal Australian Navy aims to maintain a fleet of 12 to 14 major warships along with patrol boats and auxiliary ships. While fleet numbers have remained relatively static, the vessels have grown in size, capability and complexity over the decades as illustrated in Table 3.1.

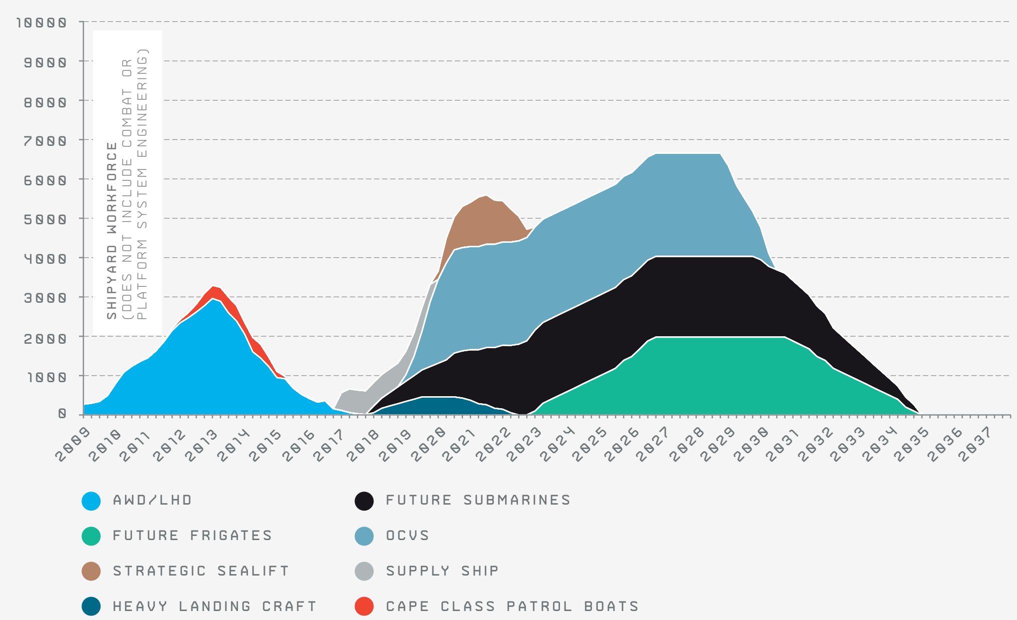
TABLE 3.1: ROYAL AUSTRALIAN NAVY FLEET STATISTICS

	1992 FLEET	2012 FLEET	2030s FLEET
SUBMARINES	Five Oberon class (2,030t)	Six Collins class (3,050t)	12 future submarines
DESTROYERS	Three Perth class (4,600t)		Three Air Warfare Destroyers (6,700t)
FRIGATES/DESTROYER ESCORTS	Five Adelaide class (4,100t) Three River class (2,600t)	Four Adelaide class (4,100t) Eight ANZAC class (3,600t)	Eight future frigates (4,000+ t)
PATROL BOATS	13 Fremantle class (220t)	14 Armidale class (305t)	20 offshore combatant vessels (2,000t)
MINEHUNTERS	Two Bay class (180t)	Six Huon class (720t)	
SURVEY VESSELS	HMAS Flinders (750t) HMAS Moresby (2351t) Four Paluma class (310t)	Two Leeuwin class (2,550t) Four Paluma class (310t)	
AUXILIARY SHIPS	HMAS Jervis Bay (8,915t) HMAS Success (18,000t) HMAS Tobruk (5,800t) HMAS Westralia (40,900t)	HMAS Choules (16,200t) HMAS Sirius (25,020t) HMAS Success (18,000t) HMAS Tobruk (5,800t)	Two Landing Helicopter Dock ships (27,500t) Two supply ships
HEAVY LANDING CRAFT	Three Balikpapan class (316t)	Six Balikpapan class (316t)	Six landing craft heavy

The Defence Capability Plan 2011 set out a naval shipbuilding program that resulted in a total shipyard workload profile as shown in Figure 3.1. This is not a financial budget graph, rather it is a graph of calculated shipyard workload expressed as full time equivalent workers at a reasonable rate of productivity. Note also that this particular graph does not include the shipbuilding work done in Spain for the main hulls of the two Landing Helicopter Dock ships. The Defence Capability Plan 2012 made some changes to the naval shipbuilding programs, but the problem that became characterised as the 'valley of death' was still present.

The schedule set out in the Defence Capability Plan presents a problem: a steep decline in activity that has already started reaching to almost zero in 2017, followed by a massive increase in activity a few years later from 2020. If all these ships were to be built in Australia, local industry would struggle with the loss of skilled people, then a demand profile that is very steep and peaks higher than current capacity. The consequence would be

FIGURE 3.1: POSSIBLE SHIPYARD WORKLOADS UNDER THE DEFENCE CAPABILITY PLAN 2011



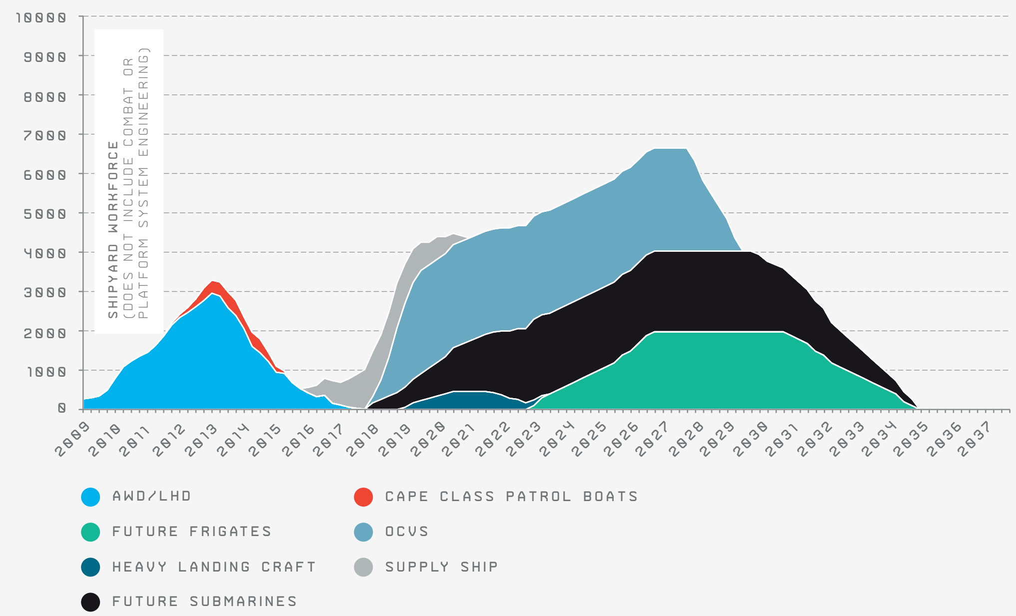
Note: (1) While not a project in the Defence Capability Plan, the workforce numbers of the Cape class patrol boats have been included to show the current workload of the Australian naval shipbuilding industry.

(2) The AWD schedule was rebaselined in late 2012 and now extends through to 2019.

higher costs and schedules that would not meet Defence's timelines. Even with a mix of onshore and offshore construction, the acquisition of these new vessels will require careful management to ensure Australian shipyards are ready for this work, can operate at reasonable productivity levels and are able to deliver ships in the timeframes required.

Today, skilled and experienced people are being lost across the naval shipbuilding industry as work on current projects moves into different phases. Several of the shipyards have started to reduce the size of groups that work on early phases of a shipbuilding project; for example people involved in ship design and block structural fabrication. People are being recruited for the new phase tasks, such as electricians. This reshaping of the workforce will continue as the projects complete each phase, for example Air Warfare Destroyer will complete hull block fabrication in about 2015.That workforce changes have already started places a priority on reviewing shipbuilding plans to ensure key skills are not being unnecessarily lost.

FIGURE 3.2: POSSIBLE SHIPYARD WORKLOADS UNDER THE DEFENCE CAPABILITY PLAN 2012



Note: (1) While not a project in the Defence Capability Plan, the workforce numbers of the Cape class patrol boats have been included to show the current workload of the Australian naval shipbuilding industry.

(2) The AWD schedule was rebaselined in late 2012 and now extends through to 2019.

PROBLEMS TO BE SOLVED

CAPABILITY AND CAPACITY

The most recent experience with the Air Warfare Destroyer and Landing Helicopter Dock projects identifies some of the problems and consequences that Defence and industry face, except that the much larger volume of work and greater complexity that is typical of a submarine project would mean the consequences would be much greater.

The impact of rebuilding from a low base on the Air Warfare Destroyer and Landing Helicopter Dock ship projects was substantial and expensive. At the outset of these projects, the premiums in the prices tendered was considerable. Analysis conducted for the DMO showed that the effective rate of assistance ranged from about 30 per cent for the AWDs to over 100 per cent for some LHD options, and amounted to billions of dollars. It is important to understand here that this was the price differential between a cold start shipyard and a fully operational, proficient shipyard—rather than the difference between local or overseas build locations. If Australian shipyards had the opportunity to build skills and experience and improve productivity, they too would offer lower prices.

The shipyards invested tens of millions of dollars in their facilities and equipment. In Adelaide for example ASC invested more than $100 million in building a new shipyard. The Government of South Australia invested over $300 million in the construction of a Common User Facility, which includes a shiplift, wharf, large hardstand area and training centre. BAE and the Government of Victoria invested over $85 million in upgrading facilities at the Melbourne shipyard. The shipyards in Adelaide, Melbourne and Newcastle needed to recruit and train a workforce of more than 600 people in a short time, and more since.

As is typical of all manufacturing activities, such new workforces start with low productivity which leads to larger labour budgets on a project.

The low base in terms of facilities and people also meant schedule was impacted. For legitimate, practical reasons, at Second Pass neither project could present a schedule that met the original warship delivery dates specified in Defence's capability plans.

This cold start also caused problems for the projects. As one much publicised example of the problems encountered, there were production issues at the beginning of AWD hull block fabrication. This was fundamentally due to lack of experience across production engineering and production supervision. The ultimate impact of this issue was a project delay of about 18 months and extra costs in the order of $200 million when all direct and indirect costs are accrued. Another example is that the production engineering effort required for the projects was underestimated because there were not sufficient experienced people who knew the real scale of effort required to prepare even existing designs for production in a new shipyard.

What is also evident from the Air Warfare Destroyer project is the benefit of experience. Experience has a substantial impact in a large, complex naval shipbuilding projects. The benefit is not simply limited to better workforce productivity; other substantial benefits accrue: initial project estimates are more accurate, risks are better understood and problems that cause additional cost and schedule blow outs are avoided. The AWD project inherited the core of the combat system team that did the successful Collins submarine replacement combat system project. This experienced team has been able to execute their work on schedule and budget; and they had the knowledge and resilience to deal with problems as they emerged.

WHY WE NEED A PLAN

The problems described here are typical of an industry in a rebuilding phase, and the impact of these issues can amount to billions of dollars for individual projects. Given the greater magnitude and complexity of work in the future, especially for the future submarine project, the cost and schedule impact of a cold start would be much greater than for the current projects. With the cost of all planned naval projects being somewhere above $75 billion, a proficient and productive shipbuilding industry would produce overall savings to the Defence budget in the tens of billions of dollars. If future projects involve new designs or more developmental systems for platforms and combat systems, then a whole new set of problems can be anticipated, with additional consequences for cost and schedules.

The other obvious challenge with the naval shipbuilding program as it stands is the increasing volume of work. Figures 3.1 and 3.2 above show that shipyard workloads would more than double if all the work was done in Australia. One solution is to purchase some of the ships overseas; however, even if that is done, the capacity of local naval shipbuilding will still need to grow.

A key lesson learned from current projects is that Australian naval shipbuilding capacity can increase, but the rate of growth has a practical limit. As illustrated in the graphs above, the issue is not the height of the peak, but the slope to get there. The size of the Australian manufacturing industry and competition for skilled workers is discussed in section 9. The conclusion is that building a sustainable naval shipbuilding industry involving about 5,000 shipyard people can be achieved, and would be a key part of an Australian manufacturing sector that employs around one million people.

SHIPBUILDING PRODUCTIVITY

Integral to the question of how many people are required to build these warships in Australia is the question of productivity. As described in section 8, the Defence Materiel Organisation has been benchmarking the planned and actual productivity of Air Warfare Destroyer shipyards each year. Shipyard productivity is being measured using an internationally recognised gauge of man–hours per compensated gross tonne.

Today, shipyard productivity on the Air Warfare Destroyer project is low by world standards for small, naval construction activities. 'Small' means a low number of ships in a build project—less than six. This is a like-for-like comparison: there is no value in comparing high volume or commercial shipbuilding to low volume naval projects like Air Warfare Destroyer and Landing Helicopter Dock ships. The productivity gains that can be achieved are substantial, and are not small percentage margins. The Air Warfare Destroyer project should achieve a productivity of about 80 man–hours per compensated gross tonne in its short run of three ships.

World benchmarks for small, naval projects are as low as 50 man–hours per compensated gross tonne. This difference in productivity between 110 and 50 man–hours per compensated gross tonne produces a cost difference of about $5 – 10 billion for direct shipyard labour when applied to the whole scheme of planned naval shipbuilding projects. There would be further savings in labour costs throughout the supply chain as productivity and efficiency increases.

In regard to the future of naval shipbuilding in Australia, if the industry is given the opportunity to build skills and experience, and invest in facilities, then production costs can be substantially reduced. With good productivity, the total workforce required to build all the ships planned for Navy would be about 5,000. This would be a small, proficient, innovative and competitive Australian naval shipbuilding industry.

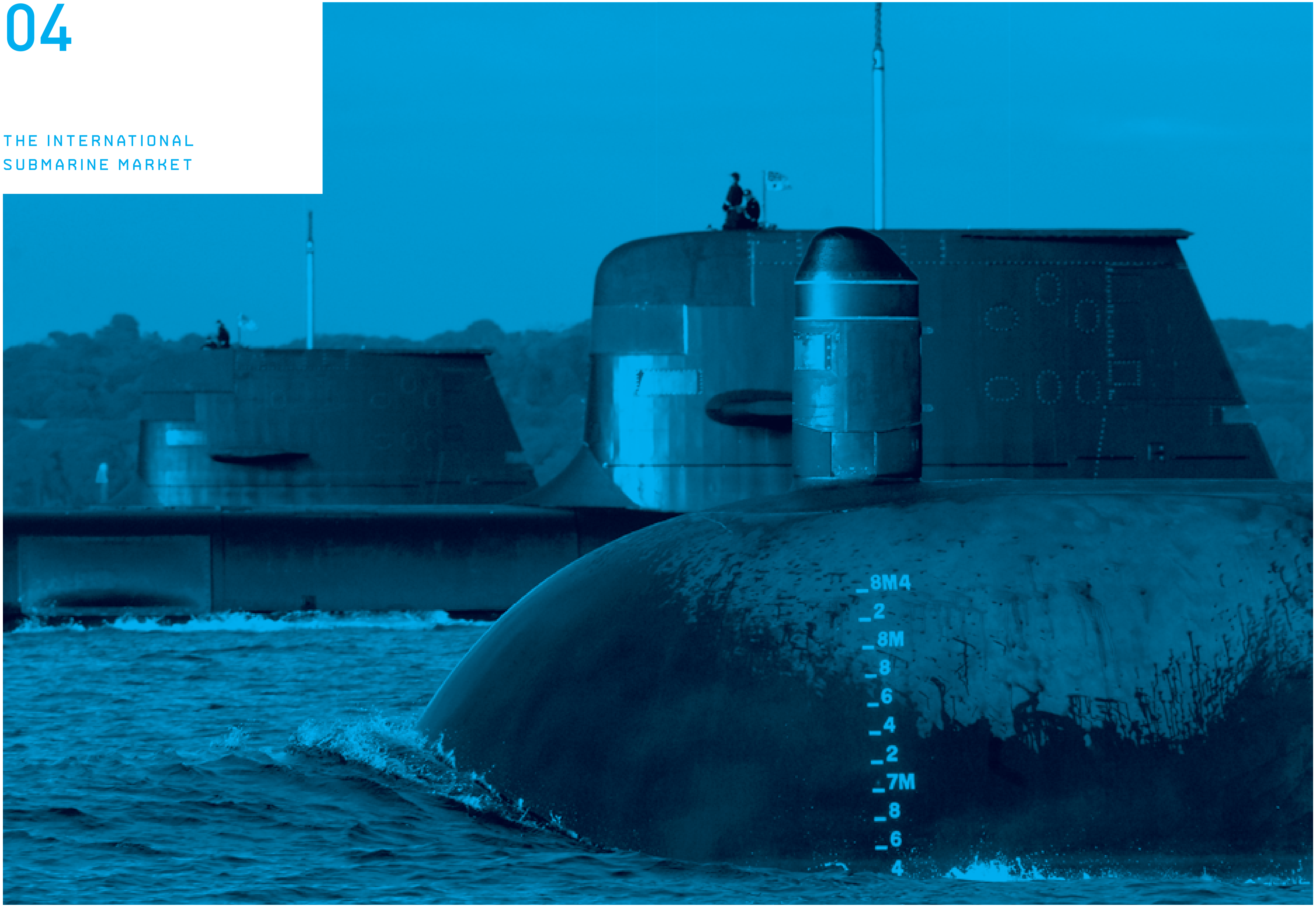
CONCLUSION

Recent experience on the Air Warfare Destroyer and Landing Helicopter Dock projects in Australia demonstrate the problems and consequences of a cold start for a major shipbuilding project. This emphasises the importance of having a good number of genuinely experienced shipbuilders at the core of a project, and the importance of planning for a steady, not rapid, growth in shipbuilding capacity. The cost savings can be measured in billions of dollars.

What has been achieved since 2009 is impressive—Australia's naval shipbuilding industry has grown from a low base to a workforce of over 4,000 people across four shipyards. It proves that Australia can grow its shipbuilding capacity and that it is capable of building complex warships. However, today some of these skills are being lost as current shipbuilding projects move into new phases, which places an imperative on Defence to review its plans to ensure skills that will be important to the future submarine project are not being irretrievably lost.

04

THE INTERNATIONAL SUBMARINE MARKET



THE INTERNATIONAL SUBMARINE MARKET

COUNTRIES WANTING TO OPERATE SUBMARINES TODAY EITHER DESIGN AND BUILD VESSELS FOR THEMSELVES, OR CONTRACT FOREIGN COMPANIES THAT ARE ALLOWED TO EXPORT THEIR DESIGNS OR SUBMARINES.

Countries that design and build submarines fall into two broad categories:

- those with a domestic demand large enough to sustain the national design and build capability over the long term
- those with a domestic market that is not big enough to achieve that viability.

Countries without a viable domestic market must export their designs or submarines to provide the volume of work needed to sustain their industry. They either build submarines in their shipyards or, increasingly, the vessels are built in the purchasing nation. Where this occurs, there is usually a high level of technical help between the parent designer/builder and customer nation.

Submarines for export are not built speculatively, but only to fill firm orders. There are no production lines in the traditional factory sense. They are based on designs that evolve slowly over time, usually with some tailoring to meet the specific requirements of each buyer. They are expensive, built in low numbers and have a life of 20 to 40 years. Customers usually buy between two and six at a time, so purchases are made infrequently—typically every few decades at most.

For countries that export submarines or submarine designs, the sensitivity of key technology is an issue that is managed very carefully. Designing nations that invest heavily in research and development for their own purposes usually keep the best technology for their own use and export less capable designs and equipment.

SUBMARINE PRODUCTION SINCE WORLD WAR 2

Before World War 2 the submarine was a developmental weapon. Great leaps in capability occurred during the war and the demonstrated utility of the submarine accelerated development. Designs began as fairly simple but evolved quickly. Submarines did not take long to build and were generally not in service very long. These characteristics enabled countries that produced submarines to easily sustain their skilled design and shipyard workforces.

Until the late 1960s, submarines were submersible ships. The submarine design and operating concept was such that the vessels spent much of their time surfaced and were submerged only to meet operational demands. Designs were relatively simple and countries with basic industrial skills could build the ships.

Three technological advances in the following two decades contributed to a staggering change in capability:

- the explosion of computing technology
- the advent of highly reliable solid state electronics applied to submarine weapon systems and guided weapons
- nuclear propulsion.

These developments transformed submarines into potent strike weapons with very long range and endurance, and capabilities that went well beyond just sinking ships.

New generation submarines are designed to spend little time surfaced, and mostly remain submerged to avoid detection by increasingly pervasive surveillance capabilities. Stealth in all the various detectable signatures—acoustic, thermal, visual, magnetic and electronic—has attracted ever increasing attention and investment in research and development.

New capabilities have developed rapidly and have also been incorporated into vessels, including anti-submarine as well as anti-shipping capability, intelligence collection, surveillance, reconnaissance, mine warfare, land attack using missiles, support to special forces, and unmanned vehicles. As a consequence, submarines have become much more expensive: their increasing complexity means design, integration and build all take much longer. The advanced technology now used has become much more sensitive and therefore more closely guarded and less likely to be made available by the countries developing it.

CURRENT SUBMARINE PRODUCTION

Countries that are self-sustaining in submarine design and production are China, France, Japan, Russia, the United Kingdom and United States. The United Kingdom and United States design and build only nuclear powered submarines. Only France and Russia offer conventional designs or submarines for export.

Germany and Sweden have exported conventional designs and submarines for many years because their domestic markets are too small to sustain an industrial base. South Korea and Spain are new exporters but both are yet to sell a design of their own. South Korea has a contract with Indonesia to build submarines based on a German design.

SUBMARINE EXPORTS AND PRICES

Germany's Howaldtswerke-Deutsche-Werft GmbH (HDW) is the most prolific exporter of submarines. In the past five decades, 36 submarines have been produced for the German navy, while 120 complete submarines or material components have been delivered to foreign navies. HDW has exported the Type 207 and Type 210 to northern European countries, and Type 209 to South American countries, southern Europe, Indonesia, South Korea, India and South Africa. More recently, the German company's exports have included five Dolphin class submarines to Israel, Type 209PNs to Portugal and Type 214s to Greece, Turkey and South Korea. These submarines are all 2,000 tonnes or less.

The French company DCNS is the world's second ranked submarine supplier with sales of Daphne and Agosta class submarines to Portugal, South Africa and Pakistan. The Daphne design was also sold to Spain and locally built for the Armada. In 1990 Pakistan began manufacturing three Agosta 90 submarines. More recently, the French Scorpene design has been sold to Chile and Malaysia with local manufacture of a further six in India and four in Brazil. Again, these submarines are all 2,000 tonnes or less. India leases nuclear submarines from Russia, while Brazil has purchased the technology to manufacture a single nuclear powered submarine of about 5,000 tonnes.

Kockums of Sweden is a relatively new entrant in the export market and Spain's Navantia shows aspirations. South Korea is a new exporter following its recent contract to provide three Type 209 submarines to Indonesia.

The submarines these suppliers offer are all designed for similar, generic operating concepts so they appeal to the largest number of buyers in a difficult market. As a consequence they are all similar in size, capability and performance. The markets they target make them very different to the Collins class submarines designed for Australia.

Imported submarines are not necessarily cheaper. Accurate data on real prices, either for complete submarines or technical support for local build programs, is very hard to obtain. The reported price generally only represents the amount paid to the submarine builder for the bare boat. The cost generally excludes the combat system, weapons and communications equipment, which are often provided to the builder as government furnished material.

Subsidies expressed as offsets or some other device play an important role in most sales. Another factor is trade incentives and cheap long-term financing by the exporting nation, for example loans made to Greece and Portugal to purchase submarines.

Exchange rates also affect quoted prices. The price for a Type 214 or Scorpene is often quoted at about US$500 million. This is misleading as this figure related to number of commercial sales when the US dollar was at parity with the Euro, which has since declined. Based on recent sales, the current cost for European built submarines of around 2,000 tonnes is between Đ500 and Đ600 million, which equates to US$650 to US$800 million. These estimates do not include government furnished equipment as discussed above.

SECURITY AND INDUSTRIAL CONSTRAINTS

The advanced technology used in modern submarines is the result of substantial investment in research and development, and delivers the operational advantage all nations pursue for their military equipment. For reasons of national security and industrial sensitivity, the countries that develop the technology closely guard it. This creates challenges for countries like Australia that do not produce much in the way of original submarine technology and so must purchase most of it from overseas.

For reasons of national security, nations usually keep their best technology for their own use and export less capable designs or submarines (complete or systems). From a national security and industrial perspective, any country making submarine technology available to another will be very sensitive to that technology finding its way into the hands of a third country. Licensing submarine technology intellectual property and classified data is therefore tightly controlled, and only the minimum information necessary to construct or operate the submarine is released. Australia's experience with the Collins class program has shown how difficult it can be to manage intellectual property.

The practical implications of this are significant. For example, the limited release of information and intellectual property constraints mean that a purchasing country is bound to the parent design company or nation for all design development work through life. The situation is more complicated if major systems are provided by different nations and data has to be tightly controlled to ensure no crossover. For example, with the Collins class submarine, Australia has to ensure United States data is not revealed to Sweden (in compliance with US International Traffic in Arms Regulations), and must ensure Swedish data is not revealed to the United States.

FUTURE CONVENTIONAL SUBMARINE PRODUCTION

The international submarine market has more suppliers than foreseeable demand can sustain. Australia's future submarine program is the biggest planned conventional submarine acquisition publicised in a world market. There appears to be little else in prospect, and none of it very certain. With the recent global financial crisis and the increasing cost of submarines, there seems little chance of this trend being reversed so the future of current players in the market is uncertain.

Only Japan and South Korea have announced plans for new conventional submarines of a similar or larger size to the Collins class. In both cases, they will be indigenous programs that will not help the survival of European builders. Unless Germany, Spain and Sweden go on to place additional orders for new submarines, the future of the industry in those countries is uncertain at best and potentially bleak. For the next 10 to 20 years, Australia's future submarine program may be as big as the rest of the world's demand for conventional submarines combined.

A number of navies, particularly in South America, operate old submarines and have not announced replacement programs—rather they have extended the lives of their existing vessels. Likewise, it is unclear whether the Netherlands, Norway and Canada will replace their submarines when they reach the end of their lives in the 2020s, although the Netherlands appears to be considering a life extension of its current boats.

The only real potential for submarine sales in the medium term is in the Asia Pacific region. Thailand, Indonesia and Taiwan have all expressed interest in new submarines, but have not followed through with budgets or orders. Again, these submarines are all in the small coastal class of approximately 2,000 tonnes or less. India is looking to replace its HDW Type 1500 and Russian Kilo class submarines and have announced a $10 billion program to build six conventional submarines, larger than the Scorpene class. These are planned to include air independent propulsion systems.

With the emergence of Russia and possibly China as submarine suppliers—both likely to be offering products at lower prices than western builders—countries seeking to replace or buy submarine capability may well look to these countries for their future needs.

SUMMARY

Submarines are not products that are readily available from a production line—only nine countries have the ability to both design and build a submarine in their industrial base. Setting aside nuclear powered submarines, that number reduces to seven for conventional submarines. While several other nations build submarines, they depend on one of these principal nations for design and technical assistance.

There are substantial constraints on the global market for submarine design. They concern both national security and industrial sensitivity, and have a real impact on what countries can purchase and under what conditions.

Firstly, as countries typically do not allow the sale of their best technology, exported submarines will be less capable than the parent design, and so will not provide the same level of security to the importing nation. What is usually considered highly classified information—the performance of the purchasing nation's submarines—is now also known to and dependent upon the country exporting the submarines.

Secondly, intellectual property controls mean that countries purchasing submarines must depend on the support of the exporting nation for the life of the vessel.

Future indications are that the number of companies and nations both designing and building submarines will reduce, so market supply will shrink. Despite the current global financial situation however, market demand for conventional submarines could reasonably be expected to rise in the longer term.

If Australia purchases submarines or designs from overseas, we obtain less than best technology and so consequently a sub-optimal level of operational capability. Importing the technology also means that another nation possesses and has control over classified data that is important to Australia's national security.

As the number of suppliers diminishes, the current perceived price advantage for buyers—created as a consequence of the global financial and market situation—is also doubtful. A reduced number of suppliers also reduces the range of submarines available, and these will be less likely to suit Australia's needs.

A nation can only really call itself a builder of submarines once it both designs and constructs its own boats. Building Collins was a first for Australia, but the submarine is a Swedish design. While we did a good job on the project, it does not make Australia a fully fledged submarine building nation.

05

STRUCTURE AND SCOPE OF REPORT

STRUCTURE AND SCOPE OF REPORT

THE 2009 DEFENCE WHITE PAPER ANNOUNCED THE AUSTRALIAN GOVERNMENT'S INTENTION TO PURCHASE 12 CONVENTIONALLY POWERED SUBMARINES WITH GREATER RANGE, LONGER ENDURANCE ON PATROL, AND EXPANDED CAPABILITIES COMPARED TO THE CURRENT COLLINS CLASS SUBMARINE.

In 2012, the government announced four options that are being considered for the future submarine:

- an existing submarine design available off-the-shelf, modified only to meet Australia's regulatory requirements
- an existing off-the-shelf design modified to incorporate Australia's specific requirements, including combat systems and weapons
- an evolved design that enhances the capabilities of existing off-the-shelf designs, including the Collins class
- an entirely new developmental submarine.

This report does not discuss the acquisition strategy for the future submarine program or the strategic or military need for submarines. Whether Australia needs submarines and, if so, the capability and numbers required, is a matter for Defence and other national security analysis.

It is also outside the scope of this report to debate the broader macro-economic policy aspects of building warships in Australia versus purchasing them at a cheaper price overseas. There are certainly more than just economic issues to consider when looking at a local shipbuilding industry, and arguments can be made for and against the concept. In the end, it is a decision for government. This report does however examine the international market for submarines and discusses current and future pricing of such overseas purchases.

While the analysis takes into account the effects that different options may have on skills requirements, details on how each should be pursued, and the advantages and disadvantages of various commercial models, are implementation details the program is yet to finalise.

SUSTAINMENT

This report does not provide a full analysis of the workforce needed for warship sustainment. Much of the activity involved in building ships is not directly relevant to supporting those ships in service. The tasks are different and while there is an overlap of some skills, particularly in platform design and systems development, the levels of effort are certainly not the same. The key link between acquisition and sustainment is the transfer of engineering know-how and data in both directions.

To sustain a warship effectively, knowledge is required of the platform design. But sustainment requires nowhere near the number of people with those skills as is needed to create the design. For combat systems, knowledge of the architecture and design is required for sustainment, but the level of effort needed in this area depends on the rate of change to operational requirements that drives system upgrades. This connection means that the future submarine and other shipbuilding projects are in competition with warship sustainment for only some of the skills.

In Australia, build and sustainment teams tend to be separated by geography (see Figure 5.1). In general, warships are built in Newcastle, Melbourne, Adelaide and Perth, but are home ported and maintained in Sydney, Perth and Darwin. Perth appears the only common location, but the build and sustainment work is very different there: Austal builds small aluminium patrol boats, but BAE Systems and ASC and other companies are involved in maintaining large steel frigates, submarines and support ships. No doubt there is some crossover of people, but the two activities are separated to the extent that each workforce is largely dependent upon its own demand factors.

Where competition between the two activities will be an issue for the future submarine project is in Adelaide. ASC and its supply chain in Adelaide is currently focused on sustaining Collins class submarines, specifically the full cycle dockings which are deep level maintenance activities and take about three years for each boat. ASC is also the lead shipbuilder for the Air Warfare Destroyers, manufacturing hull blocks in its shipyard and consolidating the entire ships on the Government of South Australia's Common User Facility adjacent the ASC shipyard.

FIGURE 5.1: CONSTRUCTION AND SUSTAINMENT IN AUSTRALIA

There is also potential for a project to extend the service life of the Collins class, which is currently referred to as the Collins Service Life Evaluation Program. While this is not an approved Defence project and its scope is yet to be defined, it would be like a mini-submarine project and involve design, systems development, production engineering, production, and finally test and activation.

The nation's submarine workforce may be stretched to meet the needs of both the evaluation program and future submarine project, but with proper coordination, the Service Life Evaluation Program should be seen as an excellent opportunity to grow the skills required for the future submarine project.

When construction starts on the future submarines, Defence and the various companies involved will have to manage workforce demand to ensure those other activities are not impacted. One option is to migrate all Collins sustainment to Perth, so ASC's submarine workforce in Adelaide can be dedicated firstly to the Service Life Evaluation Program, then gradually to the new submarine project.

—
STRUCTURE AND SCOPE OF REPORT
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THE REPORT

Much has been written on the subject of navy shipbuilding, its challenges and rewards, its problems and their fixes.

This report has been written for those with a general knowledge of navy shipbuilding and in no way covers every aspect and detail of what is an endless topic. To keep the report a reasonable length, indepth data and detailed explanation of the analytical rationale that underpins the findings has been kept to a minimum.

The aim of the Future Submarine Industry Skills Plan is to build the plan to build the skills to build the future submarines. It will also examine all navy shipbuilding projects now underway and new projects included in the Defence Capability Plan. The skills plan must also focus on projects preceding the Future Submarine Program because Australia's ability to execute this depends on our preparations before it starts. The skilled people who are ready on day one to start building our future submarines will be key to their successful delivery. No doubt skills will be further developed as the project progresses, but success is laid down in the earliest stages of the project. One expert on systems engineering, Eberhardt Rechtin, puts it simply: "all the serious mistakes are made the first day".

STRUCTURE

The first sections in this report have set the scene and rationale for developing the Future Submarine Industry Skills Plan for Australia.

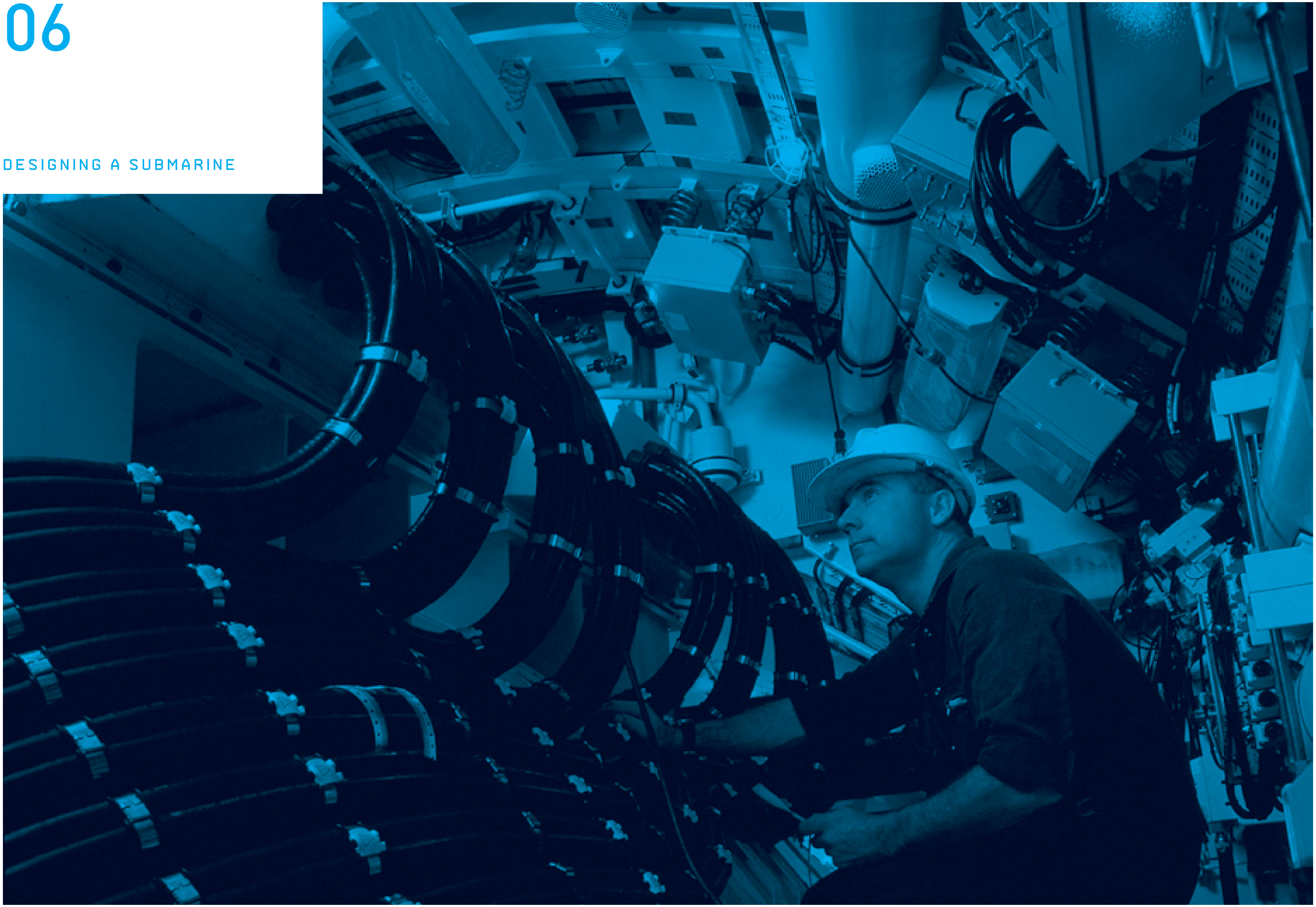
The next three sections will examine the skills needed to deliver the future submarine project. This analysis is structured in three parts: designing a submarine, developing the complex systems to install onto a submarine, and manufacturing the submarine.

One section will deal with the wider Australian workforce setting which encompasses navy shipbuilding and how skills can be developed with education and boosted through migration if necessary.

The last sections of the report outline the plan. This report will present principles rather than explicit recommendations, with actions to cover the four levels of skill as defined in this report: individual skills, workforce numbers, proficiency and experience. A vision for the long-term future of Australia's naval shipbuilding capacity is presented. The report also includes a series of overall conclusions and recommendations.

06

DESIGNING A SUBMARINE



DESIGNING A SUBMARINE

THIS SECTION DESCRIBES THE CHALLENGES OF DESIGNING A SUBMARINE, THE SKILLS AVAILABLE IN AUSTRALIA AND THE SKILLS REQUIRED FOR THE TASK. IT DEALS MAINLY WITH THE HULL, MECHANICAL AND ELECTRICAL SYSTEMS, INCLUDING HULL FORM AND PHYSICAL INTEGRATION OF THE COMBAT SYSTEM. THE DESIGN OF THE COMBAT SYSTEM, AND OTHER INTEGRATED DATA SYSTEMS, IS DEALT WITH IN SECTION 7 ON SKILLS FOR SYSTEM DEVELOPMENT.

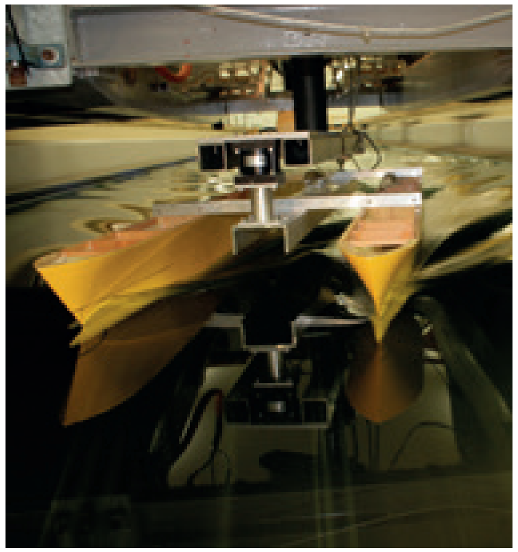
AUSTRALIAN WARSHIP DESIGNS

Australia has designed warships in the past and today possesses good skills in naval architecture, meant in the broadest sense as the people involved at all levels in the design, construction, maintenance and operation of marine vessels. Australia has not designed a modern, large naval support or amphibious ship, destroyer or submarine from first principles, but has extensive experience in the adaption of designs to local requirements. Australia, specifically the West Australian company Austal, has designed modern high speed ferries, patrol boats and surface combatants.

Over the last 20 years Austal has developed an innovative and self-contained approach to vessel design from first principals, through the completion of approximately 110 first of class designs from concept to production and vessel delivery. Austal designed the Bay, Armidale and Cape class patrol boats for the Australian Navy and Customs Service. The Cape class is an evolution of the bay and Armidale designs, and the benefits of this evolution are described in the following case study.

Through international competition, Austal designed the Independence variant of the Littoral Combat Ship (LCS) for the US Navy and are contracted to build ten of these warships. The Austal LCS design is an innovative trimaran construction, which incorporates features developed in collaboration with the Australian Maritime College and Defence Science and Technology Organisation. Austal also adapted their commercial high speed ferry concepts to produce the Joint High Speed Vessel (JHSV) design, with contracts to build ten of these vessels for the US Navy and US Army.

Sustained and developed over the years, Austal has developed in–house an efficient and effective design process. While they have not designed a destroyer or submarine, the team has skills that would make a useful contribution to the future submarine and other naval projects. However, this know how is now being eroded with Austal in the process of downsizing its design capability due to a lack of new orders.



CASE STUDY :

AUSTAL CAPE CLASS—A THIRD GENERATION DESIGN

Drawing from the experience of designing, building and maintaining the Australian Customs and Border Protection Service's Bay class patrol boats in the late 1990s, Austal created its 56 metre Armidale class patrol boat design for the Australian Navy in the early 2000s, with 14 boats built between 2004 and 2007. In 2011, Austal then developed its third generation of this design, the Cape class, for Customs. This design benefitted from the experience of building the Armidale vessels as well as feedback from navy crews and people who have been maintaining those ships for many years. Cape class also benefited from experience with design and build of the LCS and JHSV ships. Some of the development are listed below.

Comparative values between Armidale and Cape class patrol Boats (CCPB)

- CCPB has 20% more range.
- CCPB has 30% more internal volume for only two metre increase in length.
- CCPB can carry 40% more transportees in better comfort.
- CCPB operates with 40% fewer crew.
- CCPB crew accommodation is 7% quieter.
- CCPB is 5% faster for same displacement.
- CCPB garbage store is 500% larger.

From build lessons learned on Armidale, the Cape class design incorporates;

- Modified structural and equipment arrangements to improve installation efficiency by facilitating better access.
- Changed build sequence to allow more access during hull assembly.
- Manufacturing feedback improved control of weld shrinkage and material distortion.
- Increased number of switchboards to simplify electrical system upgrades.

From operational lessons learned, the design incorporated;

- Increased internal volume of the ship to maximise crew comfort.
- New arrangements for transportee accommodation on main deck improve access for persons with reduced mobility.
- Changed boarding party room location to enhance operational efficiency and safety through improved access to the ships boats and proximity to the bridge.
- Optimised ventilation in machinery and internal spaces by modelling air flow using Computational Fluid Dynamics.
- Improved materials and detail design to simplify maintenance.

DESIGNING A SUBMARINE

THE SUBMARINE CHALLENGE

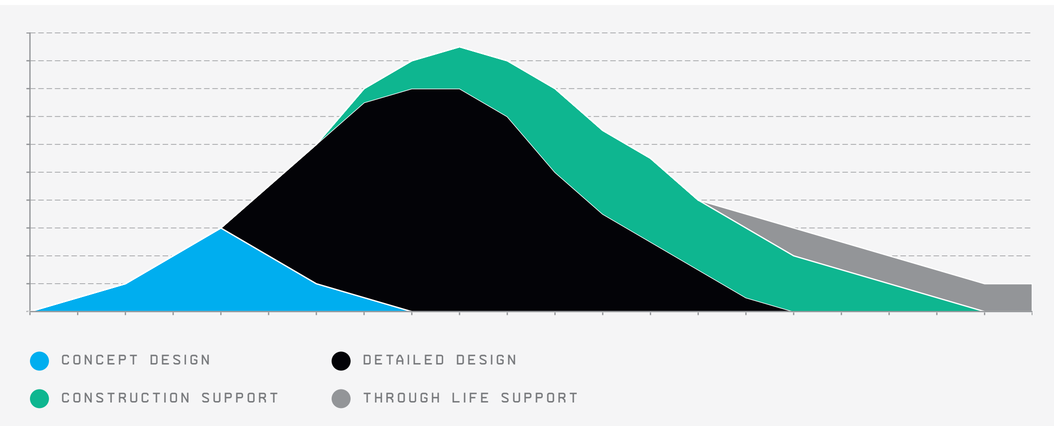
Much has been written on the challenge of designing a submarine and preservation of the specialist skills required. Most recently, the Defence Materiel Organisation commissioned the RAND Corporation to report on the skills required to design the future submarine. RAND has authored many similar reports in the United Kingdom and United States. Skills Australia also published a report on the skills needed to deliver the future submarine project.

As section 1 illustrates, submarines are very sophisticated machines and take hundreds of skilled people several years to design. The process begins by defining the top level requirements and works its way through all the systems engineering steps described in section 2. This process of decomposing and allocating requirements, understanding technology, working within budgets and other engineering constraints applies to all elements of the submarine including its hull structure, propulsion and combat system. Ultimately all elements in the design have to be harmonised to fit inside a functioning submarine.

This includes aspects such as the combat system, propulsion system and power supply as well as factors that are not as obvious such as the crew's daily living needs. Properties such as acoustic signatures and boat survivability also need to be designed and balanced to meet the specification. One of the primary requirements of a submarine when submerged is that they need to remain neutrally buoyant, and maintain stability with little or no forward motion. This means that what may appear superficially to be small changes in any one of these elements can lead to significant re-design of the boat.

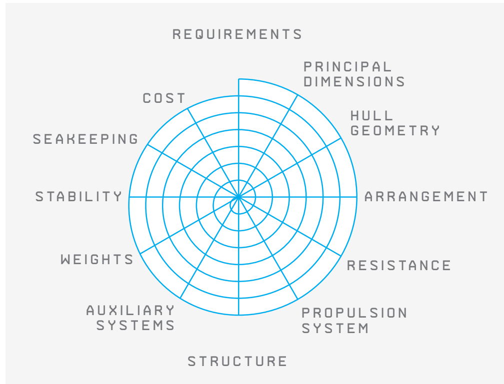
RAND and other agencies describe a design effort that starts with developing concept designs, merging to detailed designs, then support construction and ultimately through life support. Various labels are used to describe this process, and it can be performed in isolated sequence or concurrently. The following diagram is the sort of time–effort profile used to illustrate the design activity. The cycle of concept design to detailed design to construction support repeats itself many times through life as capability upgrades and obsolete equipment replacement is required.

FIGURE 6.1: DESIGN ACTIVITY



Designing is an iterative process with designs conceived, tested and changed, at an individual equipment level and ultimately integrated at the whole system (submarine) level. The process used in the Air Warfare Destroyer evolved design (ultimately not selected) and detailed in the RAND report is described as spiral, and is shown in the following diagram.

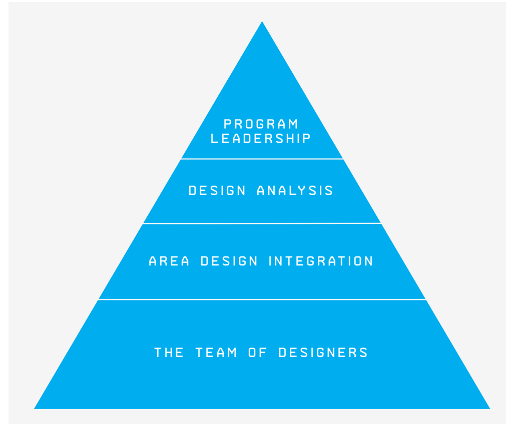
FIGURE 6.2: SPIRAL DESIGN



Source: J.H.Evans, Basic Design Concepts,Naval Engineers Journal, Vol.71, No.4.Used With Permission. Rand MG1003-2.2

To create a design requires a range of skills, a workforce with the capacity to complete the task in the time allocated, and a workforce with the tools, data and processes to develop and verify the design in a proficient manner. The last and, to most commentators, most important ingredient is experience. In RAND and other reports on the topic of submarine design, it is always clear that experience in submarine design is critical to the success of any practical endeavour. The following diagram often accompanies the diagram above and provides a simple illustration of the hierarchy of importance of the elements that make a good design team.

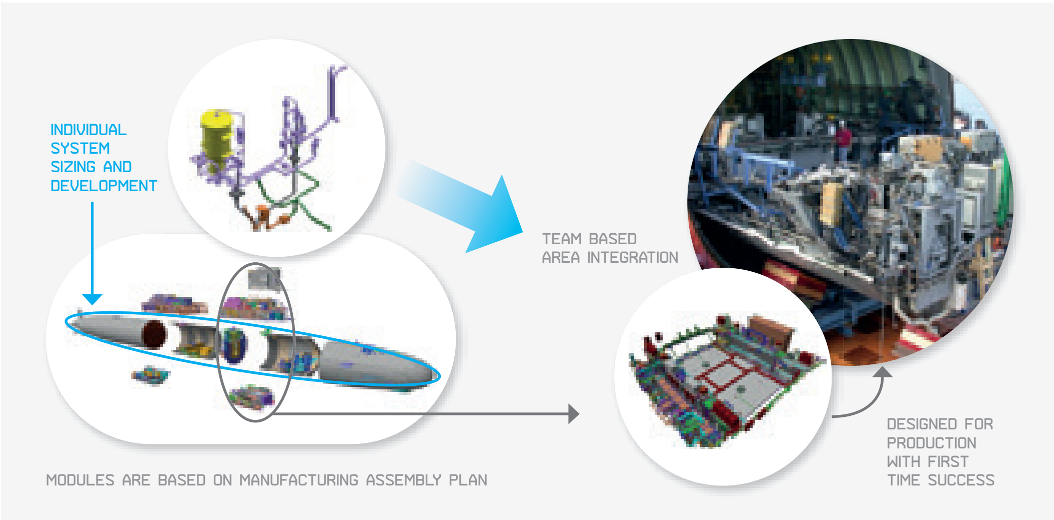
FIGURE 6.3: TEAM HIERARCHY



The diagram stresses the importance of leadership from experienced people and the importance of analysis and area design. The analysis level, about 20 per cent, represents the experts, typically engineers, that validate performance characteristics including shock survivability, signature management, war fighting and so on. This involves computational analysis and other modelling of the various aspects of the submarine design and requires an extensive and coherent set of tools and processes, the sort of resource only possessed by experienced submarine design organisations. The area design level, again about 20 per cent, represents the skilled team leaders experienced in the efficient creation of integrated submarine designs. The process is shown in the following picture.

DESIGNING A SUBMARINE

FIGURE 6.4: THE DESIGN PROCESS



Beyond the engineering skills needed to design a modern complex surface combatant vessel, submarine designers must consider submarine-unique requirements such as underwater hydrodynamics, stealth, survivability, atmospheric control, noise, signatures and safety. For example, a submarine's unique safety criterion is withstanding the enormous pressures at maximum dive depth. Figure 6.5 from the RAND report shows the wide range of skills and competencies required in designing a submarine.

The output of the design effort will include a large three dimensional computer model of the submarine and all elements within (3D CAD model). From this will be extracted the general arrangement and other two dimensional drawings, which will be used in the construction process.

Computer files of the different computational analysis and performance modelling will be provided to demonstrate performance. Material specifications, equipment lists, test procedures and a vast array of other technical documentation will also be produced. This effort is immense: the page count for the drawings and documentation of a submarine design will run into the tens of thousands.

FIGURE 6.5: COMPETENCIES REQUIRED IN SUBMARINE DESIGN

SKILL COMPETENCIES		EXAMPLE ACTIVITIES/PRODUCTS
DRAFTSMEN	Electrical	Electrical system component, electrical analysis, electrical design, power generation
	Mechanical	Mechanical component, mechanical system, mechanical system design
	Piping/HVAC	Piping design, heating, ventilation, and air conditioning design, fluid system design, hydraulic system design
	Structural/ arrangements	Structural engineering, structural arrangement, system design
ENGINEERS	Signature analysis	Acoustic, wake, thermal, electromagnetic and other signature analysis
	Combat systems and ship control	Combat system integration, combat system design, ship control and navigation
	Electrical	Electrical motor and generator designs, distribution, control, load analysis, component design and safety
	Fluids	Hydraulics, chilled and cooling water, flow analysis, computational fluid dynamics (CFD), flooding and casualty analysis
	Mechanical	Mechanical components, mechanical systems, mechanical design, weapons-handling systems, rotating machinery, auxiliary machinery
	Naval architecture	Hydrostatics, hull equalibrium, speed and powering analysis, stability
	Planning and production	Scheduling, manufacturing planning, production strategy development, producibility analysis, production support, zone and block outfitting, procurement
	Structural/ arrangements	Hull design, casing design, deck layouts and design,equipment arrangements, shock analysis, foundation designs
	Testing	Component and system testing, test and trials plan development
	Management	Programme management, technical management; supervision
	Engineering support	Non-engineering support, such as technical computer and information technology specialists
	Other engineering	Life cycle support, cost, availability analysis, risk management, safety, environmental, materials

Source: RAND MG-1033, figure 2.1

DESIGNING A SUBMARINE

PRODUCTION ENGINEERING

It is important to recognise that finalising the design is not the end of the engineering effort. In simple terms, the design is a description of what the submarine has to look like when it is finished. What also happens in parallel with the functional design is production engineering, which also encompasses design. The shipyard team has to develop a build strategy, manufacturing plans, build sequences and schedules, bills of material, assembly and test procedures, and more to enable construction of the submarine. Shipyard design effort includes designing jigs and fixtures to aid construction, bracing and support systems. The output of this effort is an equally large set of drawings and documentation that enables the production workforce to build the submarine. Production engineering is described further in section 8.

RAND REPORT

In 2009, the Defence Materiel Organisation engaged RAND Corporation to answer four questions:

1. What is involved in designing a new submarine and what is the demand for various design resources during the design program?
2. What design resources currently exist in Australia?
3. What is the gap between what is needed and what is available?
4. What is the cost and effectiveness of options for closing the gap?

Publicly released in December 2011, the RAND report *Australia's submarine design capabilities and capacities* opened with the following statement:

> The Commonwealth of Australia will need a domestic workforce of roughly 1,000 skilled draftsmen and engineers in industry and government to create and oversee the design of a new, conventionally powered submarine for the Royal Australian Navy. Although a workforce of this size and capabilities does not exist in Australia today, under the right circumstances one could be cultivated over the next 15 to 20 years. However, the Commonwealth could shorten the duration and lessen the costs of designing a new submarine if it were to collaborate with foreign design partners rather than rely exclusively on a domestic workforce to design the vessel. (RAND MG-1033, pg xxiii)

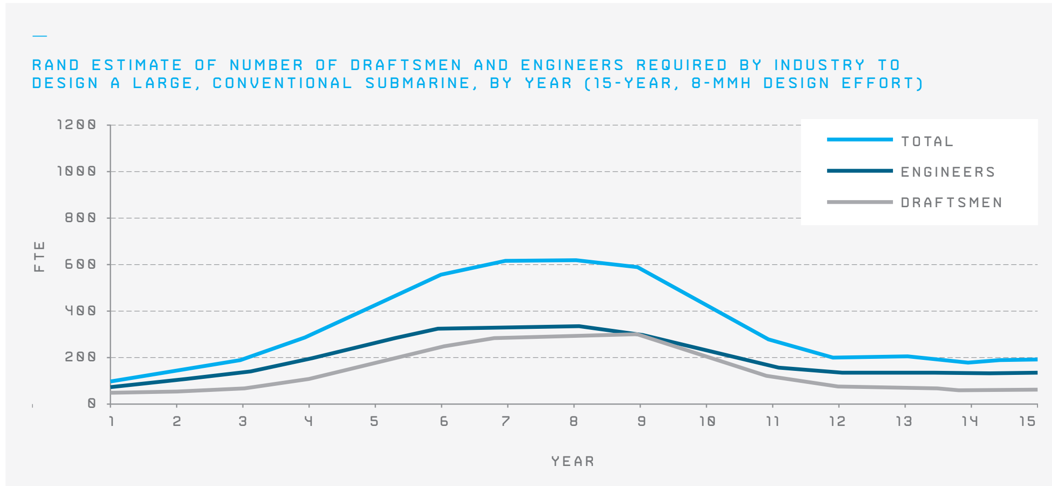
The intent is not to summarise the entirety of the RAND report, but there are key observations that are central to this broader study.

FUTURE SUBMARINE DESIGN WORKLOAD

In terms of workforce capacity, there are many decisions yet to be made in the progression of the Future Submarine project that are critical to determining the effort required to design the new submarine. It is simply too early to say precisely how many people will be required. Furthermore, the time allowed in the schedule to complete design will obviously determine the peak workforce required.

RAND identified an upper and lower number of hours it believes are required to design the future submarine. The range was eight to 12 million man-hours. This equates to a peak design workforce of between 600 and 900 engineers and draftsmen. This workforce profile for a 15 year design period is shown in Figure 6.6.

FIGURE 6.6: ESTIMATE OF DESIGN TEAM REQUIRED



Source: RAND MG-1033, figure 3.6

The assumptions in RAND's analysis are worth examining. For the purposes of its work, RAND reasonably assumed the future submarine will be a new design—larger and more complex than Collins—with the first boat delivered 15 years after design commences. Of the other assumptions, two stand out that lean toward the higher person hour estimate being the more likely scenario. RAND discusses the interpretative power of the construction shipbuilder, that is the ability of the shipyard workforce to work off less detailed information because of extensive experience and ingrained know-how. Experience on contemporary shipbuilding programs has been that more effort than expected has been required to provide a sufficient level of design information to the shipyard planners and production workforce. This is understandable given the inexperience levels of the new workforce. For the future submarine, the higher level of effort will be required, what RAND describes as the 'US model'. Given the experience level of the design workforce is more likely to be low than high, it should be expected that the design effort will be at the higher end of the scale, towards 12 million man-hours.

In general, these man-hour numbers compare reasonably to other projects, although such comparisons always require caution because of the many different ways these numbers are recorded and quoted. The design effort on the Collins class was about seven million man-hours, the Royal Navy Upholder class was similar and the US Navy Virginia class about 18 million man-hours. Today's submarines are taking more time to design because of increasing complexity, more challenging performance requirements and more stringent safety requirements. This will be true for the future submarine.

DESIGNING A SUBMARINE

RAND also used a workforce model to estimate the impact of experience levels of people in a workforce. It found that man-hours would increase by 14 to 18 per cent if only 20 to 40 per cent of the Australian experienced workforce was available, noting that there are too few workers with experience to meet the peak demand. RAND's view on individual productivity and experience is shown in Figure 6.7.

Similarly, the schedule increases by two to four years using the same assumptions. This is shown in Figure 6.8, where inexperience results in slower than planned progress with design, and production cannot commence until design products are ready, typically around the peak of the work profile.

Throughout its analysis, RAND highlights a caution that almost all of the submarine experienced people now working in Australia are fully occupied working on Collins sustainment, the Air Warfare Destroyer or other projects. At the time when future submarine design would start, expected to be in the latter half of this decade, much of this work will still be continuing: Collins sustainment will be ongoing, with the potential of additional work for the Service Life Evaluation Program, and while the Air Warfare Destroyer project will finish in early 2019, new projects such as the future frigates and offshore combatant vessels will replace it. Caution is required to believe the situation requires little or no action.

DESIGN TECHNOLOGY AREAS

The RAND analysis breaks down this task of designing a submarine into three functional technology areas: combat systems, hull form design, and internal hull, mechanical and electrical (HME) systems.

FIGURE 6.7: INDIVIDUAL PRODUCTIVITY LEVELS BY YEARS

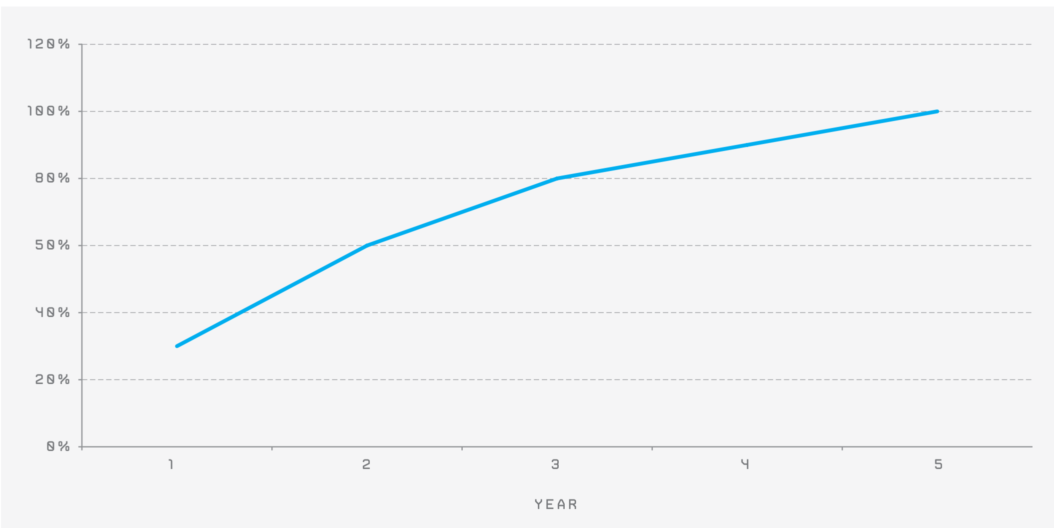
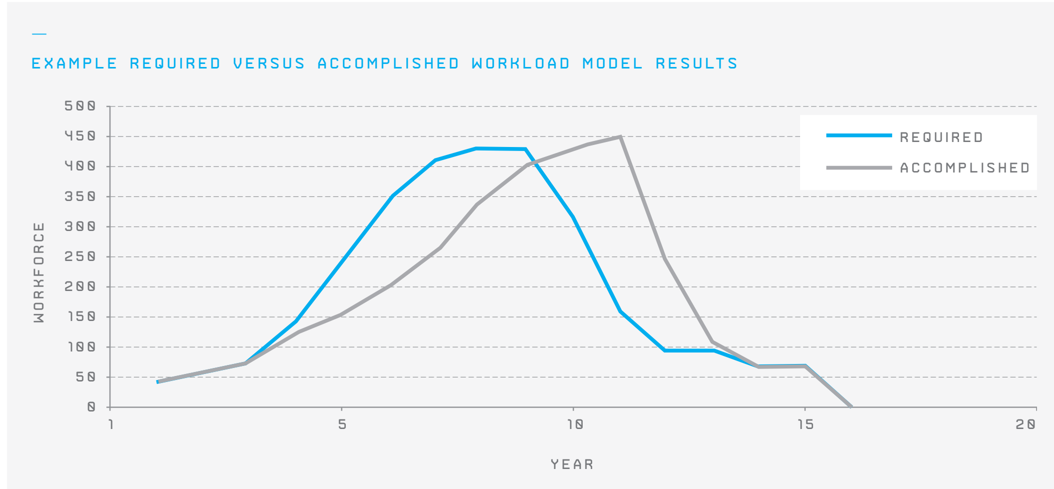


FIGURE 6.8: RESULTS OF WORKLOAD MODELS



Source: RAND MG-1033, figure 11.1

COMBAT SYSTEM DESIGN

RAND concludes that Australia has sufficient engineers with applicable technical and management skills, and facilities to support future design. This can be strengthened in terms of skills, experience or capacity by company reach-back and partnerships with foreign companies and governments. This study has reached the same conclusion, but key questions remain about how to: 1) simply retain the existing workforce; and 2) improve their skills. This is discussed in section 7.

HULL FORM DESIGN, AND INTERNAL HULL, MECHANICAL AND ELECTRICAL SYSTEMS

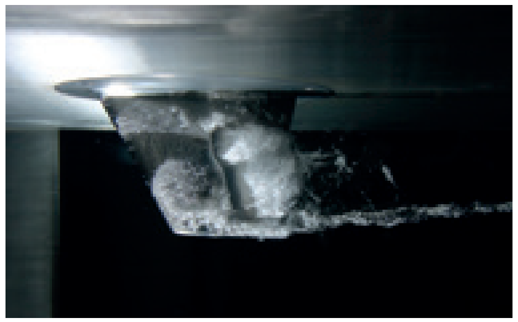
In terms of hull form design, RAND also concludes that Australia has a core group of skilled people capable of supporting a new submarine design, but stresses that there is the 'big difference between individual research projects or engineering modifications to the Collins class and being responsible for the design of a hull form on a new submarine' (RAND MG-1033, pg 179). There is a very real risk of underestimating the sort of enterprise it takes to successfully develop a fully documented new submarine design.

When building complex warships like a destroyer or submarine, Australia has typically worked from existing designs. Adapting an existing design to Australian requirements and Australian build is not a trivial task, and sometimes even that has been under estimated. For example, it is generally said that Australia under estimated the task of evolving the Swedish (Kockums) Västergötland submarine design for the Collins class.

The expert industry panel involved in this study was unanimous in its view that Australia had a good range of skills that could contribute to the design of a complex warship like a destroyer or submarine, with such a project requiring the partnership of an established, overseas designer.

DESIGNING A SUBMARINE

RAND identified a greater problem for the future submarine in the design of hull, mechanical and electrical systems. The hull form of nuclear powered and conventional submarines is similar in their design challenge, so partnering with other governments and international firms can bring the skills required to the task above those already available in Australia. On the other hand, the internal mechanical and electrical systems in a conventional submarine are noticeably different to a nuclear submarine. It is likely that the future submarine will be bigger than the Collins class submarine, and while very capable design support can be obtained from the international vendors of the various sub-systems, there will be a new design challenge in harmonising all of these systems into what may be one of the largest conventional submarines around.



AN AUSTRALIAN PLATFORM DESIGN

If a new platform design is to be created for the future submarine, the likely practical approach is that Australia would partner with a foreign company and government. Those organisations would bring to the task not only skilled, experienced leaders and designers, but also their proven set of tools and processes. Australia would set the requirements for the new design, but the process would be managed by the established company, with the backing of its government.

In the United States, this is referred to as integrated product and process development.

A core group of Australians would be integrated into the team according to their skills, along with new local recruits. Some Australians would assist in developing the design, others would perform a government oversight role, and others would focus on preparing for an Australian build. Similarly, some of the tools being developed in Australia would be merged into an existing structure.

The following paragraphs look at each of the four aspects of the term 'skill' being used in this report: individual, team numbers and capacity, proficiency and experience.

SKILLS GAP—INDIVIDUALS

At the education and training level, neither the RAND report nor this study have identified any specific university or trade course that is not available in Australia and which may be needed to provide the basic qualifications required to design the future submarine. Indeed, the RAND report had many good things to say about the Australian Maritime College in Launceston, Tasmania:

> 'The Australian Maritime College appears unique, offering both undergraduate and graduate-level courses in naval architecture, marine and offshore systems, and ocean engineering. The college offers significant expertise and facilities that both industry and the government could leverage in designing a future submarine.'

It would be a worthwhile collaboration for the Defence Materiel Organisation and the Australian Maritime College to work together to develop and enhance the design skills base in Australia. Of note, it was disappointing to hear that NSW TAFE recently cancelled their Naval Architecture courses at the Sydney Institute, which had a reputation of producing good graduates with practical skills.

SKILLS GAP—WORKFORCE SIZE

RAND's conclusion is that if the new design option is selected, there are not enough experienced submarine designers in Australia or all the necessary facilities, tools and processes. RAND also observes that because of the demands of Collins sustainment and other naval shipbuilding projects, there may be only 100 to 200 submarine-experienced draftsmen and engineers available to support a new submarine design. With the support of the expert industry panel, this study agrees with that conclusion.

This confirms that an experienced design partner (either company or government) will be required if Australia decides to build submarines based on a new design. The suggestion that Australia could alone embark on a plan to put together its own submarine design capability within the timeframe of a single project is not practical. Not only would it take an extraordinary amount of time, designing a submarine is a skill that requires real work to build up a design philosophy. It requires a substantial investment in experimental submarine design and build projects, and it is unlikely the first attempt will meet all requirements. When a design partner is selected, it is not the static design of their latest submarine that is important, rather it is the heritage of experience that has built a design philosophy and codified set of design practices and specifications.

Australia should make every effort to retain the group of skilled shipbuilders that it has now. We have a team of combat system engineers working on the Air Warfare Destroyer and Landing Helicopter Dock projects as well as ANZAC and Collins upgrades, and the submarine hull form and hull, mechanical and electrical engineers are doing some work in updating Collins submarines, but they are likely to move onto other projects if there is no further work in the maritime sector. Arranging the other naval shipbuilding projects that precede the future submarine to retain and develop the skills of those people will be an important action for Defence. They need to be kept working. It might be on new platform design challenges or working on designs to support upgrades or obsolescence in existing ships. It does not even have to be pure design work: it might be general engineering work to support a maritime project. While design skills fade when people are not engaged in designing a submarine, the fact that they are working on, say, a support ship project will at least retain these people in the shipbuilding industry. The disappearance of skilled people is a much worse problem than fading skills.

Building the number of people in the workforce, and increasing all their skill and experience levels, is clearly the objective of the plan. Having people work on the new projects, getting them to deal with the front end engineering task that such an enterprise requires, whether it includes new design or not, is one action to build skills. Starting on engineering tasks for the future submarine, be they parameter modelling of concept designs or detailed designs of certain sub-systems, can be another useful action. Taking an equipment design through to land-based testing is important proof of effort, and such experiments are great learning opportunities. This work needs to be more than just a high-level concept design—it needs to reach into detailed design for production. Work on hull, mechanical and electrical sub-systems for conventional submarines should be a focus, including air independent propulsion. All this work should engage the Defence Science and Technology Organisation in the science and technology aspects, and Defence in terms of safety and other engineering requirements. Using new technologies in the future submarine will increase design work, and might possibly call for new skills.

Such planning has commenced in the Future Submarine Program Office in the Defence Materiel Organisation.

There is an important difference between:

- the level of experience in individuals in a workforce (the above analysis)
- the experience level of a unified team, which is discussed below.

SKILLS GAP—PROFICIENCY

Proficiency in submarine design depends on the whole enterprise of people, facilities, tools, data and processes.

In terms of facilities, RAND identified that organisations such as the Defence Science and Technology Organisation and the Australian Maritime College have good facilities to support certain aspects of design such as tow tanks and cavitation channels. Not unexpectedly, Australia does not possess all the facilities desirable in developing a new submarine design.

The one facility RAND specifically identified as needed by Australia was an integrated propulsion/energy test facility. This land-based test site would integrate all elements of the propulsion and energy systems including diesel generators, propulsion motor, energy systems (batteries and possibly air independent propulsion), electrical distribution, cooling and associated test and recording systems. Government has announced plans to establish such a facility. When the design partner is selected, it will then be possible to determine what facilities are available in the collective design team, the gaps and whether they can be obtained elsewhere or should be built in Australia.

In terms of tools and processes, because Australia does not have an experienced, proven submarine design capability, it naturally does not have the full suite of tools necessary to complete the task. In partnership however, Australia will obtain the tools and processes required. The issue for this study is the skill of Australian people to work within the framework of tools and processes established for the enterprise. Becoming proficient in this environment is not a trivial task, and allowing time for this learning will be an integral part of the design schedule. The early selection of design partner and establishment of the design development environment will allow this learning to start and not cause delays.

Another option already suggested is to second Australians to international submarine design houses to gain experience with the tools and process and creating designs, especially detailed designs. Maximum benefit will come from this investment if people are seconded to the selected design partner, which again reinforces the value of early selection. This mentoring of Australians by the design partner should continue right through the life of the project, and would be especially important if Australia is to stand up a complete design capability for the following generation of submarines.

SKILLS GAP—EXPERIENCE

The RAND analysis described above dealt with the relationship between experience and productivity of the individual. The chart at Figure 6.7 shows that a person with only two year's experience in submarine design is 60 per cent as efficient as someone with five years. A cure to this problem is to employ more people, and while that increases costs to some degree, it will not cause project failure.

Where experience really counts to project success is at the higher levels of project leadership. As depicted in the diagram at Figure 6.3, particularly important to success is experienced leadership of the design project, and of the area design teams that produce the integrated arrangements of each submarine hull block. The density or packing factor achieved in a submarine drives complexity, and requires a higher skill level to produce designs for efficient block construction.

Australia has a number of people with the skill and decades of experience to lead these teams. What is particularly important however is to retain these senior people and ensure organisations have effective succession plans to bring up the next generation. As mentioned above, this needs Defence to optimise its schedule of naval shipbuilding projects to sustain a reasonable work program for these people, both in industry and Defence. Ultimately, it will not be possible to fill all the key positions with Australians and some experienced people will undoubtedly come from our design partners.

COLLINS SERVICE LIFE EVALUATION PROGRAM

Collins class submarines have a design service life of 28 years and Defence is investigating options for an extension. The Service Life Evaluation Program for Collins is considering various design modifications that would be required to overcome reliability and maintainability problems and equipment obsolescence.

The program can be seen almost as a submarine design and build project on a smaller scale. The project steps of concept and detailed design, engineering for construction and through life support, followed by construction work on the submarines themselves, would be replicated in a life extension project. The Service Life Evaluation Program would provide a learning platform for a workforce that will be engaged for the future submarine program. The team at ASC's submarine design organisation, Deep Blue Tech, could gain experience by designing the modifications required, engineers would be engaged in integrating the system upgrades into the platform while the production workforce would make the required changes to the platform.

MILITARY OFF THE SHELF DESIGN

If the future submarine is not a new design, but an evolved or updated design, the project will still require designers. If the option to update the Collins design is chosen, the project will need a sizeable platform design team to work through equipment obsolescence, reliability and other known performance issues with the current Collins design.

Until decisions are taken on the cost benefit trade off of difference changes, and the scope of redesign is set for the project, it is not possible to know the precise make-up of such a design team. But to differing degrees, depending on the option chosen, the project will need area design teams as well as individual sub-system designers. The changes proposed will need to be verified at the whole boat level, with analysis work into submarine survivability, stealth, safety and other criteria. The whole redesign will need to be captured in an integrated product data environment and controlled by an integrated product and process development like framework.

As an indication of the level of effort required, the adaption of the Spanish F-100 existing platform design for the Air Warfare Destroyer required about one million man-hours of design work. The Australian warship incorporated a newer version of the Aegis Combat System to the Spanish warships, and included a number of additional sub-systems such as a towed array sonar. From this experience, it can be seen that even the smallest changes in requirements can result in substantial effort to adapt an existing design.

SUMMARY

Submarines are sophisticated machines that require a team of hundreds of skilled people to design—from initial concept to detailed design, construction support and through life support. An experienced workforce is critical to its success.

While Australia does have a core of experienced engineers working in the combat system area, there are fewer working in hull form design, and hull, mechanical and electrical systems design. Austal has a proven capability in the design of certain classes of warship like patrol boats and one variant of the US Navy Littoral Combat Ship, but the size of this design team is now being reduced. Efforts should be made now to retain the experienced engineers, draftsman and other people currently working in the industry.

Until key decisions are made on the design of the future submarine, it is not possible to determine the effort required to design it. The 2011 RAND report estimated that around eight to 12 million man-hours would be needed to design a new submarine, or between 600 to 900 engineers and draftsmen working over 15 years. That time could be shortened if experienced submarine designers were brought into the team. A collaborative effort with a foreign design partner will be required.

07

SKILLS FOR SYSTEMS DEVELOPMENT

SKILLS FOR SYSTEMS DEVELOPMENT

THIS SECTION DESCRIBES THE COMPLEX NATURE OF COMBAT AND OTHER ELECTRONIC DATA SYSTEM DESIGN, DEVELOPMENT AND INTEGRATION. IT ALSO DESCRIBES THE SKILLS REQUIRED FOR THE TASK AND THE SKILLS AVAILABLE IN AUSTRALIA. THE MAIN FACTORS ASSOCIATED WITH PRODUCTIVITY AND PROFICIENCY OF THE SYSTEMS WORKFORCE ARE ALSO EXAMINED, INCLUDING QUALIFICATION, EXPERIENCE, PROCESSES, TOOLS AND FACILITIES.

THE COMPLEX NATURE OF MILITARY SYSTEMS

The design, development and integration of combat and other electronic data systems in warship and submarine projects is a complex activity often involving the integration of large numbers of products from multiple vendors. Layers of sub-systems need to be designed, produced and integrated to form larger systems, which in turn integrate into the overall mission system. Typically a submarine would incorporate about 70 systems and hundreds of items of equipment.

Recent major warship projects in Australia have not developed complex systems from the ground up. Australia's approach to combat and platform management systems development has instead been to select existing sub-systems and then to modify and integrate these to provide the necessary functional capability. Under this off-the-shelf approach, the systems workforce needs relatively fewer people with pure system design skills combined with a larger number of people with system architecture and system integration skills. Hardware engineers and software developers are still needed to modify hardware and software to make it compatible with the overall architecture, platform services and arrangements, and to create elements like the computing infrastructure that connects the off-the-shelf systems.

The complexity of systems development necessitates a mix of skilled people supported by sophisticated tools and processes, as well as development and test facilities. Whether Australian projects integrate existing sub-systems or develop indigenous combat or platform management systems from the ground up, both are non-trivial undertakings. Systems development starts with the definition of top-level requirements and works its way through all the systems engineering steps described in section 2.

Current warship projects in Australia have involved the development of a complete system by adapting existing combat and platform management sub-systems and installing them in an existing platform design. From this and experience on the Collins project we know systems development requires a wide range of skilled people including systems architects, naval architects, systems engineers, software, safety, mechanical and electrical engineers, as well as integrated logistics support specialists. A wide variety of specialty engineering areas such as safety, security, reliability, availability, maintainability and human factors engineering is also required. Clearly the complexity of the workforce required reflects the complexity of the activity.

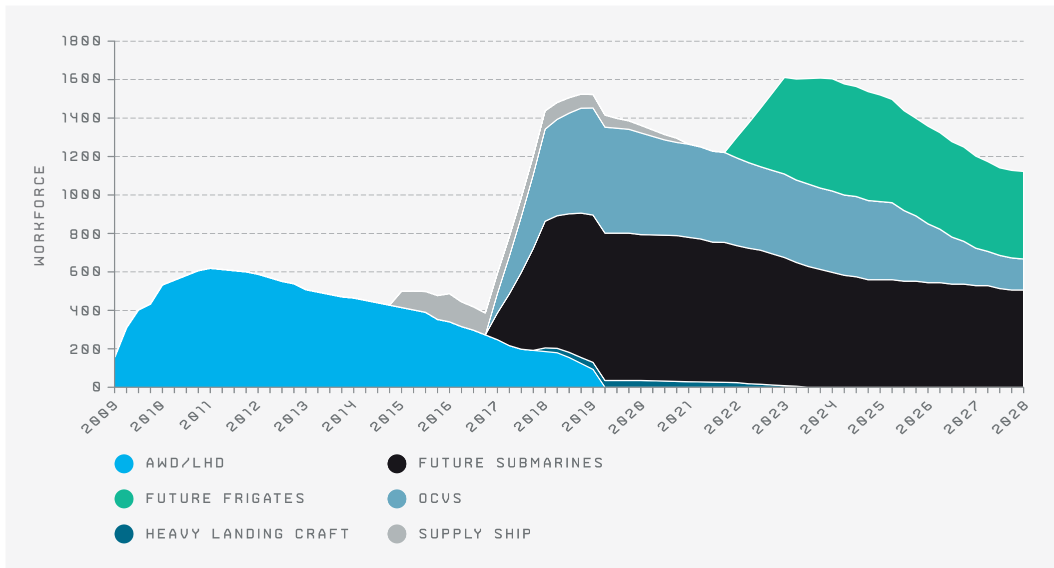
Work now being done in Australia on Collins, ANZAC Guided Missile Frigate in-service support and upgrade programs, the Landing Helicopter Dock and Air Warfare Destroyer construction, has established a good team of people skilled at systems development and support. Australia over the last few decades has also grown a group of people proficient in the design and development of sub-systems. Companies such as Thales, Ultra Electronics Avalon Systems and Jenkins Engineering Defence Systems, often working with the Defence Science and Technology Organisation have through build and in service support projects developed specialist skills and leading edge technologies in areas such as sonar systems and electronic warfare. An example is the incremental development of Australian sonar technology over the last 20 years. During this time the Defence Science and Technology Organisation and Thales have collaborated to evolve towed array sonar technology from what was fitted to the Oberon submarines to the highly capable system now installed on the Collins. This evolutionary research and development is now continuing on fibre optic and fibre laser technologies for next generation of systems.

In its 2011 report into Australia's submarine design capabilities, RAND found Australia's current capability and capacity in this area is also not limited to these specific groups, with other areas of defence (land, air and joint projects) and the non-defence engineering sector having workforces with skills that could contribute to systems development in naval shipbuilding. While these external skills can be useful, defence systems development experts say understanding the warship domain is very important.

The number of people required to successfully deliver shipbuilding projects can vary substantially with even small changes in top-level requirements. For example, during the Air Warfare Destroyer project there was an initial requirement for 64 missile vertical launch cells. That requirement could not be met with the selected F-100 platform design, which has 48. This single requirement could have driven the project to design a brand new warship, requiring a much larger workforce to design, develop and integrate both the combat and platform management systems. Given that top-level requirements can lead to substantial increases in workforce size, it is imperative that systems engineering starts early, so enough time is available for systems engineers to thoroughly check the completeness and coherence of the requirements, and to examine different solutions to find the optimum balance.

With the current profile of naval shipbuilding projects over the next 20 years, at its peak Australia will require just under three times the present workforce to support systems development, as shown in Figure 7.1. The systems workforce numbers are a rough order

FIGURE 7.1: POSSIBLE WORKFORCE TO SUPPORT SYSTEMS DEVELOPMENT UNDER THE DEFENCE CAPABILITY PLAN 2012



SKILLS FOR SYSTEMS DEVELOPMENT

of magnitude estimate based on typical ship types because the top-level requirements for each warship have not yet been finalised. The estimate has been based on the systems workforce for current projects along with Australian and international expert opinion.

SKILLS GAPS

In its 2011 study, RAND concluded that:

> "In the area of combat systems, our gap analysis suggested that industry and government have sufficient numbers of engineers with the applicable technical and management skills, as well as a sizeable facility base to support future design. In addition, both industry and government could take advantage of potential partners in allied countries."

Even in the most challenging scenario of a brand new design for the future submarine, Australia presently has about the right number of experienced people to undertake combat and platform management systems work, considering this project in isolation. However with multiple projects commencing at about the same time, the steepness of the ramp up and the level of simultaneous demand are a problem. The time gap between the ramp down of the Air Warfare Destroyer and Landing Helicopter Dock projects and the forecast ramp up exacerbates the problem for the systems companies, just as it does for the shipyards. This leads to three key challenges.

The first is that Australia needs to retain this experienced workforce if it is to be in the best position possible at the start of the future submarine and other naval shipbuilding projects. A decline in work over the intervening period as is forecast will result in real problems and substantial costs to re-establish this capability, not just in terms of workforce numbers, but more because of the loss of proficient and experienced teams. The cost is both direct in terms of recruiting and training new people, but also indirect because of the loss of productivity and the loss of experienced team leaders who can predict problems before they occur and avert costly mistakes.

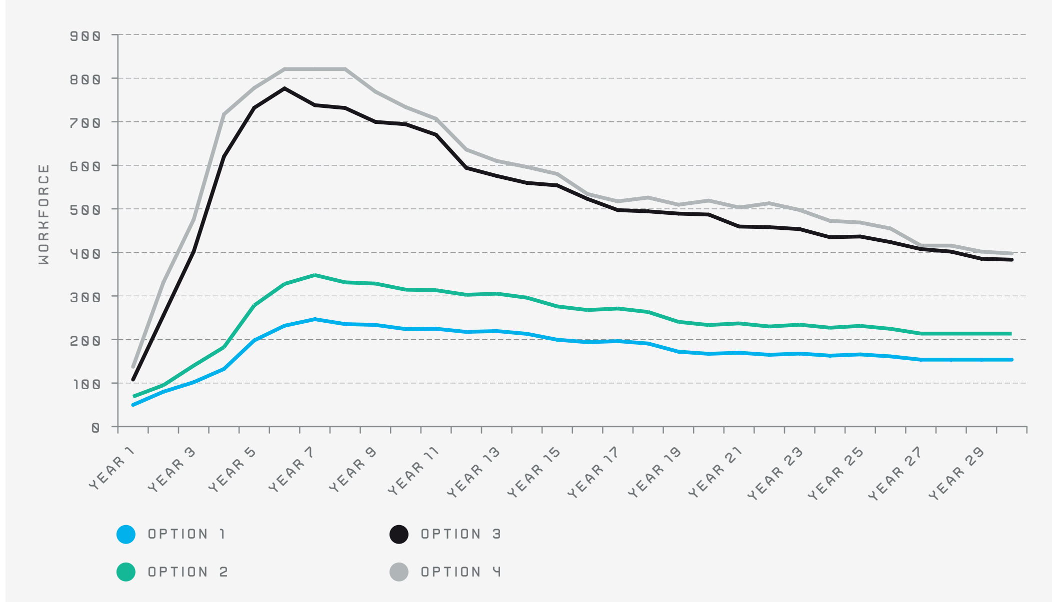
The second challenge is the current schedule for naval shipbuilding in Australia that will see three major projects commence in a short timeframe at the end of this decade. As can be seen from the estimates in Figure 7.1, companies would have a very short period to raise a workforce and it is not financially viable to recruit such a large workforce in the hope they will secure work in the future. A steadier and more controllable program is required to grow the systems workforce. As can be seen from the Air Warfare Destroyer experience, it is not the peak numbers of people required that is the challenge, it is the slope of the ramp to reach that peak.

The third challenge is to create a pipeline of new people moving into naval systems development. This pipeline allows new graduates to be trained and mentored, so they grow into the skilled, experienced workforce needed for future submarine and other projects.

Key decisions including the design option for the future submarine and underlying choices regarding sub-systems and production will dramatically affect the size and time profile of the workforce required to undertake systems development across all the projects. As a result, precise estimates of the number of people within each systems skill category needed for each future submarine option, combined with the other projects, is not possible given the number of variables.

Systems companies represented on the expert industry panel provided estimates for the systems workforce size and time profile across the options being considered for the future submarine as shown in Figure 7.2. This shows the total number of people required with systems skills will vary substantially depending on which option is chosen.

FIGURE 7.2: POSSIBLE SYSTEMS WORKFORCE SIZE ESTIMATES FUTURE SUBMARINE OPTIONS



SKILLS GAP—INDIVIDUALS

The key skills involved in developing and integrating combat and platform management systems can be broken down into a number of engineering categories and other skills as shown in Figure 7.3. Each of these skill areas has further levels of breakdown. For example systems engineering breaks down into a further 10 skills areas, but for the purpose of this report the discussion will examine skill sets at the higher level.

SKILLS FOR SYSTEMS DEVELOPMENT

FIGURE 7.3: INDIVIDUAL KEY SKILLS AREAS

KEY SKILL AREAS	
→ Systems engineering → Software engineering → Electrical engineering → Electronic engineering → Mechanical engineering → Other specialist engineering (e.g. safety, security, reliability, availability, maintainability, human factors)	→ Integrated logistics support → Supply chain management → Configuration management → Project management → Contract management → Financial management

Each of the key skill areas of software, mechanical, electrical and electronic engineering along with a number of specialist area courses such as safety, security, reliability, availability, maintainability, and human factors engineering are offered through undergraduate and post graduate study in most tertiary institutions in Australia. Training in integrated logistics support, supply chain management and configuration management are also widely offered as part of undergraduate or post graduate degrees, or stand alone courses.

In contrast, education in systems engineering is not offered on such a wide scale. At the graduate level, only The University of Queensland, the University of South Australia and the University of NSW at the Australian Defence Force Academy have regular programs. The University of Queensland's Master's Degree in Systems Engineering was sponsored through a Defence Strategic Industry Development Agreement, initially for the High Frequency Modernisation Project and then the Airborne Early Warning and Control Project. In the case of University of South Australia, its Master's Degree in Military Systems Integration has been sponsored through Defence's Skilling Australia's Defence Industry program. The other post graduate program in systems engineering is through the Royal Melbourne Institute of Technology. Typically, student numbers are small in comparison to undergraduate degrees (electrical, civil, mechanical etc.).

Systems engineering plays a critical role in the development of large complex systems for defence projects. The Australian National Audit Office noted in its report into acceptance into service of Navy capability, that "*successful delivery is dependent upon effective organisational structures, high standards of management cooperation and coordinated effort, supported by adherence to the best systems engineering practices available*" (ANAO 57, pg.17). The ANAO report also said that adopting a good systems engineering process to reach agreement on top level requirements and how to assess compliance "*at the outset of, and throughout, projects, is critical to facilitating the transition from acquisition to operational acceptance*" (ANAO 57, pg.22).

To successfully deliver the future submarine it is clear that irrespective of the option chosen, the project will need skilled and experienced systems engineers. To develop that skilled workforce, post graduate courses in systems engineering should continue to be supported by Defence.

SKILLS GAP—WORKFORCE SIZE

As stated earlier, the number of skilled people required for the future submarine and other naval projects depends on many factors such as the chosen design and relative timing of all projects. The number of experienced people available at the start is a factor that determines not only the number of new people to be recruited and trained, but also the time it will take to grow the workforce required. The rate of workforce growth is limited by the number of skilled, experienced people available to mentor new people and lead inexperienced teams.

To forecast demand, major systems companies in Australia provided estimates of the number of people required to work on the development, implementation and integration of the combat and platform systems in future submarine projects. The estimates range from a peak workforce of about 250 people in the case of a military off-the-shelf option to over 800 people in the case of a new design in Australia. Approximately 60 per cent of this workforce consists of people with systems, software, hardware and other technical skills and 30 per cent with project management, financial and other project support skills. A variety of assumptions underpin these estimates. Naturally, the time allowed for the systems development effort has a major impact on the peak numbers required, with a shorter duration requiring a much larger peak of people working in this area.

Numerous estimates exist of the number of skilled workers in the sector. From a limited survey, RAND determined that approximately 3,000 people work in systems technical disciplines in the defence sector. A 2010 study by the Defence Science and Technology Organisation and Defence Materiel Organisation into the systems integration capacity of Australian industry found that around 3,500 people work in systems development and integration in the defence sector. Depending upon which option is chosen for the future submarine, Australia either has or is able to develop over time the workforce needed to successfully deliver the combat and platform management systems required for all planned naval shipbuilding projects.

When looking at the demand for these skills across other sectors of the economy, Skills Australia, in its 2012 report *Building Australia's defence supply capabilities* analysed the projected national demand and supply for a number of major professions. For the skills categories in the systems development domain, its analysis concluded a surplus would exist for those categorised as engineering professionals.

Regardless of the design option chosen for the future submarine, the lower end estimate means Australia needs at least to retain the current experienced systems workforce. The upper end estimate means Defence and industry need to plan and control the gradual build up and professional development of this workforce to create the experienced, proficient teams required for the naval shipbuilding projects planned.

PROFICIENCY AND PRODUCTIVITY

In the design, development and integration of combat and platform systems, the concepts of proficiency and productivity are difficult to quantitatively measure as no two projects are the same. Each project has its own challenges.

SKILLS FOR SYSTEMS DEVELOPMENT

For example the systems development task on Air Warfare Destroyer involved integrating the latest variant of the US Navy's Aegis Combat System with a set of sensor and weapons systems selected by Australia from local and international suppliers. This effort required a different number and range of people as compared to the integration of the Aegis system in either a US Navy Arleigh Burke class destroyer or the Spanish Armada F-100 frigates, which have different sensors and weapons, and associated interfaces.

What is clear is that proficiency in combat and platform management system design, development and integration depends upon the whole enterprise of people, tools, processes and facilities. Qualitatively a number of factors such as well-defined requirements, the early involvement of industry, the retention of key personnel, the use of simulation, and the early adoption of organisational structures, processes and tools are major factors in enabling a productive systems workforce.

CASE STUDY:
EARLY SELECTION OF COMBAT SYSTEM AND COMBAT SYSTEM INTEGRATOR FOR AIR WARFARE DESTROYER

The Air Warfare Destroyer combat system architecture was selected in 2004 based on the US Navy's Aegis Combat System and a tender was released for the combat system integrator role in the same year. This enabled the early selection of Raytheon Australia in 2005 and its early involvement in the refinement of system requirements. Orders for long lead items for Aegis were also placed in 2005.

Defining the combat system architecture early provided a stable foundation for other ship design elements to be developed. Early selection of key elements within the architecture, such as Aegis and missile types, provided a solid basis for the whole Air Warfare Destroyer design sequence and is a primary reason for the good progress that has been achieved with combat system development on the project. A stable architecture supported better equipment selection, created harmony in the design development process, and avoided the cycle of clashes that occur when trying to develop combat and platform system designs simultaneously.

In the case of the combat system architecture, there has been little change since 2007 because the early start allowed time for the comprehensive analysis of requirements and detailed development of the architecture. Principles underpinning the development of the architecture were:

- minimise total ownership cost.
- proceed with manageable risk.
- use proven off-the-shelf equipment.
- provide interoperability with Australian Defence Force, US Navy and coalition forces.
- minimise crewing.
- support technology change and capability growth.
- maintain the verification boundary of existing systems: sensor, command and control and weapons.
- Aegis maintains the master track database.
- leverage off existing Australian Defence Force infrastructure.

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SKILLS FOR SYSTEMS DEVELOPMENT
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As can be seen from the Air Warfare Destroyer case study, one of the critical success factors for systems development is the early engagement of industry, which allowed enough time for a comprehensive systems engineering process. The key industry people needed at this early stage include the chief engineer, chief system architect, and senior system engineers (typically the people who later lead the various project integrated product teams—above water warfare, undersea warfare, communications, etc.).

These people need skill and considerable experience in systems architecture, system requirements development and allocation, and systems analysis, in addition to domain knowledge. These are the sorts of people who commenced the Air Warfare Destroyer combat system integration task in 2005. Moreover, it was the same core team that had worked on the Collins replacement combat system that transitioned to the new project. The benefit of having an established proven team is much greater than generating a new team of experienced people. The team comes with people who know each other—teamwork and proven tools and processes.

Throughout systems and software engineering literature, it has been well documented that understanding and documenting requirements

early in a project leads to large cost savings in later phases. In a May 2010 report by the US Government Accountability Office, it was noted that successful projects 'pursued capabilities through evolutionary or incremental acquisition strategies, had clear and well-defined requirements, leveraged mature technologies and production techniques, and established realistic cost and schedule estimates that accounted for risk'. Cost savings made from improvements in early requirements definition are not marginal improvements but are substantial savings in the overall project budget, as well as greatly reducing the risk of schedule overruns.

Retaining experienced engineers and integrated product team leaders also drives productivity improvement in a systems workforce. The project and technical knowledge these people build up over time means practical plans are developed, previously seen problems avoided and problems encountered quickly solved. This lack of rework and overall efficiency means substantial cost savings and fewer cost blowouts. The need to retain key staff and prevent the loss of corporate knowledge was a lesson learned from the Collins and other naval projects.

The improved use of modelling and simulation to evaluate requirements and technology choices early in a project enables good decisions to be made about system architecture and sub-system selection. Simulation of combat and platform system interfaces and performance characteristics at the time requirements are still being refined provides a much better understanding of the risk and benefit of each variable and trade off, and allows the development of mature requirements and a stable systems architecture. In addition, modelling and simulation provides a cost efficient means of verifying key requirements that might otherwise be costly or dangerous to actually test. Some projects do not invest in modelling and simulation to support design development due to initial capital cost, not realising the longer term cost benefit derived from better up front decisions.

SYSTEMS DEVELOPMENT AND TEST FACILITIES

Australia has many facilities devoted to the design, development and integration of complex military systems. BAE Systems, Boeing, Lockheed Martin, Raytheon, SAAB Systems and Thales, along with many small to medium enterprises, have facilities across Australia supporting all aspects of systems development, upgrade and maintenance.

On recent projects such as the Air Warfare Destroyer and the ANZAC anti-ship missile defence upgrade, these facilities played a critical role in systems development. These facilities allow system developers to progressively test their designs and fix faults prior to installation on the ship. Doing this work after equipment is installed on the ship is very expensive, and any problems delay the entire project. So savings in time and money by land-based testing are considerable.

Often in the past, land-based test facilities have been built at the beginning of a project using the equipment from the last ship. The facility is then dismantled at some interim point in the project so the equipment can be sent to the shipyard. This leaves the project without a support facility for the final ships, and Defence without a facility for through life support, maintenance and upgrades. Unless it is a very basic system or there are only one or two ships, the best approach is to include in the project scope dedicated equipment for a land based test facility that will support both acquisition and sustainment. With careful design, the cost is relatively small in proportion to overall project budget.

Until decisions are made regarding systems design for future submarine, it is not possible to estimate the scale and precise nature of facilities required to support systems development. What is clear is that Australia already has substantial infrastructure that should support this work along with the skills and experience to adapt and extend them to meet the requirements of the future submarine project.

PROCESSES AND TOOLS

Proven processes and tools underpin team productivity and are a cornerstone of successful systems development. Organisations involved in the design, development and integration of combat and platform management systems require well-defined processes, with a matching tool set.

The ability to continuously improve processes through the adoption of a framework such as Capability Maturity Model Integration has been recognised by US Department of Defense, which mandates a Capability Maturity Model Integration Level 3. Organisations should invest in improving processes to improve systems development effectiveness and efficiency. Recent studies have shown that organisational commitment to a model that measures, guides and improves an organisation's performance, such as Capability Maturity Model Integration, benefits its systems capability, which in turn improves overall project performance.

As outlined in section 6, tools play a critical role in the successful design, development and integration of systems. Tools are required to capture and trace top-level requirements through to detailed design decisions, while other tools assist in the design and documentation of the system architecture as well as software design and development. Considerable time is spent when new teams are established in both setting up a workable tool infrastructure and on people learning to use new tools. This takes time in the critical early stage of a project, which can be avoided by engaging established teams. To improve productivity in this area, Defence should leverage off proven teams, tools, processes and accreditations in planning the overall scheme of naval projects.

EXPERIENCE LEVELS

In the area of systems design and development, it is especially important that project directors, integrated product team leaders, senior systems engineers and system architects have considerable experience in the development of large, complex systems. RAND in several studies suggests it takes 8 to 10 years working in naval systems to have the experience required to perform these roles.

As outlined in the workforce section above, estimates of the number of systems people currently working in the defence sector range between 3,000 to 3,500 people. Of this number, there are about 600 currently working on systems for the new Air Warfare Destroyers and Landing Helicopter Dock ships. There are other people working to maintain and upgrade in-service systems on the Collins and ANZAC warships.

These people represent the core of the naval systems workforce in Australia, they are skilled and experienced. If nothing is done to manage the shipbuilding workload, Australia may need to build the workforce to meet demand as outlined in Figure 7.1. As stated previously, it is very important to retain experienced systems engineers and architects to lead systems development for future projects.

Also important is the retention of experienced teams. The transition of a proven team from the Collins replacement combat system project directly to the Air Warfare Destroyer combat system meant that from the outset, the team had momentum and was anticipating and avoiding problems. What this experience shows was the speed and efficiency of a proven team. If the task had been undertaken by a newly formed team, it would have required more time and budget because of low productivity and time spent by the team working out roles and dependencies.

SUMMARY

Combat and other electronic data system design, development and integration is a complex activity that requires a range of skilled, experienced people to be successful. Australia has about 600 people working in current naval shipbuilding projects with more people working on naval systems sustainment. These individuals have the skills and experience necessary for the design, development and integration of large, complex naval systems. It takes time to grow individual skills and more time to grow proficient teams.

The key to systems development for the future submarine is to retain this workforce, preserve established teams (tools, processes and facilities), and engage the mission systems integrator early to help refine requirements and create the systems architecture. The extent to which this workforce might need to grow will be dependent on decisions about the design of future submarine and timing of other naval projects.


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THALES

08

SHIPYARD CAPACITY AND SKILLS

SHIPYARD CAPACITY AND SKILLS

THIS SECTION PROVIDES AN ASSESSMENT OF THE FOUR MAJOR AUSTRALIAN NAVAL SHIPYARDS—ASC IN ADELAIDE, AUSTAL IN HENDERSON, WESTERN AUSTRALIA, BAE SYSTEMS IN MELBOURNE AND FORGACS IN NEWCASTLE. AS WELL AS AN OVERVIEW OF THE FACILITIES, THE CAPACITY AND CAPABILITY OF EACH SHIPYARD IS ASSESSED IN THE CONTEXT OF BUILDING THE FUTURE SUBMARINE AND THE OTHER NAVAL PROJECTS IN THE 2009 DEFENCE WHITE PAPER AND 2012 DEFENCE CAPABILITY PLAN. IT ALSO COVERS THE CONSTRUCTION OF AN ANTARCTIC SUPPORT VESSEL, REFERRED TO AS AN ICEBREAKER, WHICH IS ANOTHER POTENTIAL AUSTRALIAN GOVERNMENT PROJECT. IT ALSO PROVIDES AN IN-DEPTH ANALYSIS OF THE CURRENT LEVEL OF SKILLS OF THE WORKFORCE EMPLOYED IN THE SHIPYARDS.

The information presented here has been drawn from an analysis prepared in late 2012 for the Future Submarine Industry Skills Plan by First Marine International, a consultancy group from the United Kingdom that provides specialist services to the marine industry. The company's expertise includes shipyard benchmarking, advising on improvements to existing shipyards, designing new shipyards, and shipyard performance improvement programs. It has previously conducted shipbuilding studies for the Defence Materiel Organisation, the United States Department of Defense, the United Kingdom Ministry of Defence, most recently the Canadian Government, as well as many shipbuilding companies around the world.

The data collected by the study shows that the four major Australian shipyards have the capacity to build the ships outlined in the White Paper and Defence Capability Plan, with some investment required to develop launch facilities for the largest supply ships. It also shows the shipyard workforce, currently totalling around 3,500 people, generally has the range of skills to build the ships required for the surface fleet, although there are a number of skills groups that would need to grow.

Above all, First Marine International emphasise the need to retain experienced workers in the shipyards, both for maintaining skills in the shipyard and for a mentoring role as the workforce ramps up in preparation for future shipbuilding projects. Calculations of the minimum numbers required to keep that experience in the shipyards and potential rates of growth while maintaining appropriate experience levels are made. Given the current labour market, the shipyard companies reported that they see no issues in achieving a reasonable rate of growth.

OVERVIEW OF THE MAJOR NAVAL SHIPYARDS IN AUSTRALIA

ASC

The Australian Submarine Corporation began operations in 1985 when Kockums became part of a joint venture with the Australian branch of Chicago Bridge & Iron, Wormald International and the Australian Industry Development Corporation to construct Collins class submarines. In 1987, it was selected to design and build the Collins class, delivering six boats between 1996 and 2003 before commencing a 25-year through-life support contract. The company was subsequently nationalised in April 2000 and in 2004, changed its name to ASC to reflect its position as a supplier of naval combat vessels, in addition to its original heritage of being a specialist submarine supplier and maintainer. In 2005, ASC was selected as shipbuilder for the three-ship Hobart class Air Warfare Destroyer project.

In addition to assembling and completing the ships, the shipyard is building nine of the 31 blocks required for each ship at its shipyard in Osborne, South Australia. The remaining blocks are subcontracted to other shipyards.

ASC is Australia's largest naval shipbuilding company, employing over 2,400 personnel and contractors across three facilities in South Australia and Western Australia, including more than 380 engineering and technical specialists.

ASC's Osborne facility, located 20 kilometres north-west of central Adelaide, is composed of two shipyards: ASC North and ASC South (Figure 8.1). The two shipyards are separated by the Common User Facility—part of Techport Australia, which is owned and operated by the Government of South Australia.

ASC North was where the Collins class submarines were built. It now conducts Collins full cycle docking maintenance activities. The total site area is 200,000m² and facilities include 14,000m² of covered fabrication area, 8,500m² of office space and around 5,000m² of covered warehousing. The main construction point is the hull outfitting hall which is capable of building two submarines in tandem. Launching and retrieval is carried out using the dedicated 5,000 tonne ship-lift on the ASC site. The shipyard was purpose designed for submarine construction but its layout and facilities make it suited to integration of smaller surface vessels. Although the ship-lift limits the size of vessel that can be launched, production of even the largest sized blocks required by the vessels in the Defence Capability Plan is possible.

The newer ASC South has a total site area of 140,000m² and includes 11,000m² of covered fabrication area, 4,000m² of office space and over 2,200m² of covered warehouse. The site was purpose designed for the construction

FIGURE 8.1: ASC SOUTH (LEFT), COMMON USER FACILITY (MIDDLE) AND ASC NORTH (RIGHT), ADELAIDE

of the Air Warfare Destroyer and is therefore well suited to similarly complex vessels in the Defence Capability Plan such as the frigate and the offshore combatant vessel. Similarly to ASC North, production of even the largest sized blocks is possible due to the size of the buildings and capacity of the cranes. Critically, the site is supported by access to the Common User Facility, which has the main construction, launch and wet berth facilities capable of accommodating all vessels in the Defence Capability Plan except the largest supply ships. The shiplift has been designed with expansion in mind, and can be lengthened to carry the larger supply and Landing Helicopter Dock ships.

Of particular relevance to the future submarine project is Deep Blue Tech, which is an ASC-owned company focused on submarine design research and development. There are currently about 50 people employed to create concept designs that have been used to investigate capabilities that may potentially be used on the future submarine, to identify the technologies required and to acquire the associated technical knowledge.

ASC also operates a shipyard in Henderson, Western Australia, currently dedicated to submarine in-service support. This could potentially be used as a construction point to increase capacity for a number of ship types in the Defence Capability Plan.

AUSTAL

Austal is a global defence prime contractor. Founded in 1988 and listed on the Australian Stock Exchange in 1998, Austal specialises in the design, construction and maintenance of high speed vessels for defence and commercial purposes. Austal has a global footprint with strategically located design, construction and service facilities around the world serving its three business segments: ships, systems and support and employs 5,000 staff in Australia, the United States, Asia, Europe, the Caribbean and the Middle East. Its main products include passenger and freight ferries, luxury yachts and patrol boats. Austal has designed both the US Navy's Independence class Littoral Combat Ship and the US Navy and Marines Joint High Speed Vessel and is currently constructing these at its facility in Mobile, Alabama, USA.

Austal's company headquarters and Australian shipyard operations are located in Henderson, Western Australia. This facility does defence and commercial work, employing around 500 people. Figure 8.2 shows its main shipbuilding site. In addition to this, there is a second facility approximately 500 metres along the waterfront.

The facility and its equipment are well suited to covered construction and outfitting of vessels in their primary markets such as aluminium patrol boats and large aluminium high speed ferries. Sub-assembly bays and assembly bays are contiguous and the ground transfer system delivers vessels directly to the launch facility.

The Henderson shipyard operations cover a total area of over 70,000m². Around 14,000m² of covered production area is available, over 2,000m² of office space and over 1,000m² of under-cover storage. The site has a marine railway for launching and a pier for wet berthing.

There is a second facility which was modified to provide additional sub-assembly and assembly bays with similar dimensions to those in the main site, as well as additional launching, wet berthing and office facilities. It is not currently used for shipbuilding.

At their Australian facilities, Austal have built nearly 250 vessels in its 25 year history. While its main work has been with large fast ferries, for example the 113 metre *Leonora Christina* for the Nordic Ferry Services that was launched in 2011,

FIGURE 8.2: AUSTAL'S MAIN SHIPBUILDING SITE AT HENDERSON, WESTERN AUSTRALIA

Austal also built the 14 Armidale class patrol boats (57 metres) for the Royal Australian Navy between 2004 and 2007, and are currently constructing eight Cape class patrol boats for Australian Customs and Border Protection Services.

BAE SYSTEMS

BAE Systems is a global defence company employing around 85,000 people worldwide. Products and services cover air, land and naval forces, as well as advanced electronics, security, information technology, and support services. Both submarines and naval surface ships are designed, constructed and supported within the group. The group is represented in Australia by BAE Systems Australia, which includes an indigenous shipbuilding capability.

BAE Systems Australia employs 5,600 people in its resources, aerospace, land and integrated systems, defence logistics, and maritime sectors. With over 1,300 people, the maritime division is headquartered in BAE Systems' Williamstown Shipyard, Melbourne, where just under 1,000 of these employees are located. The division's other locations are a smaller shipyard in Henderson, Western Australia, and a design office in Sydney, New South Wales. These employ around 270 and 70 employees respectively.

BAE Systems acquired the Williamstown shipyard in January 2008 when it purchased the assets of Tenix Defence. The 115,000m² site, shown in Figure 8.3, is located in the northern part of Port Phillip Bay, adjacent to Port of Melbourne commercial operations.

SHIPYARD CAPACITY AND SKILLS

FIGURE 8.3: BAE WILLIAMSTOWN SHIPYARD, MELBOURNE

The facilities make the Williamstown shipyard ideally suited to the construction of small to medium-sized frigates or similar complex vessels. The facility was recently upgraded to construct Air Warfare Destroyer blocks and to complete the Landing Helicopter Dock ships. The upgrades included new steel production workshops, block construction points and blast and paint facilities.

The shipyard's main construction point is an inclined berth, which is not optimal in the context of modern ship construction. The slipway could be modified to accommodate the wider beams (18 metres) of the large vessels. If this was done, with the exception of the submarine and the supply ship, all vessels in the Defence Capability Plan could be constructed on the inclined ways. However, there would be a productivity penalty when compared to a more modern approach to construction where hulls are consolidated and systems integrated on a level surface before launch.

There are 25,000m² of covered production area, a similar amount of office space and 5,000m² of under-cover storage. Several piers and wharfs provide block load-out and wet berthing facilities for vessels after launch.

BAE Systems Australia also operates a shipyard located within the Australian Marine Complex in Henderson, Western Australia, which could be used as another construction point to increase capacity. This site has a ship lift, dry berths and a number of fabrication facilities which have been used for the refit of ANZAC class frigates, the refit of Collins class submarines, and the production of mast modules for Canberra class Landing Helicopter Dock ships.

FIGURE 8.4: FORGACS TOMAGO (LEFT) AND FITZROY STREET (RIGHT) SHIPYARDS, NEWCASTLE

Examples of construction undertaken by the Melbourne shipyard include the 118 metre ANZAC class frigates for the Royal Australian Navy and the smaller Protector class Offshore Patrol Vessel (85 metres) for the Royal New Zealand Navy. Most recently, BAE Systems has manufactured blocks for the Air Warfare Destroyer project and is now integrating the superstructure and systems in the first Landing Helicopter Dock hull that arrived from Spain in late 2012.

FORGACS

The Forgacs Group is Australia's largest privately owned ship construction and repair company, serving commercial and naval markets in a number of locations. The company has facilities in Newcastle, Sydney, Brisbane and Gladstone. Forgacs balances its involvement in the commercial shipping and engineering sectors with defence contracts. The Forgacs Group employs about 800 people in Newcastle on the Air Warfare Destroyer project.

Forgacs has two principal shipbuilding sites near Newcastle. The first is Tomago shipyard, a 73,000m² site about 10 kilometres north-west of Newcastle. The second is Fitzroy Street, a 38,000m² site in Carrington leased from the NSW Government. Both shipyards are shown in Figure 8.4.

The two sites provide a total of about 15,000m² covered production area, 4,000m² of office space and 3,000m² of under-cover storage. However, part of the covered block assembly area is provided by temporary shelters, which is not ideal, and much of the equipment is dated.

The site at Tomago has two land-level construction points using either a hydraulic tipping side launch or tapered way side launch, neither of which is optimal in the context of modern ship construction. Both would require re-commissioning and dredging may be required. This type of launch method means the shipyard is unsuitable for the integration of submarines and frigates.

There are also air and water draft restrictions. With some investment in facilities, the shipyard could potentially be used for the integration of icebreakers, heavy landing craft and supply ships. There are no wet berths but a shipping berth provides block load out capability for all vessel types.

The Fitzroy Street shipyard has a construction hall suitable for the integration of the small patrol boats as well as a marine railway for launching. While it does not have suitable facilities for constructing and launching the other vessel types in the Defence Capability Plan, the shipyard is capable of block construction and load out for all vessel types. A wharf provides berths for the patrol boats and vessels launched at Tomago. In addition, there are land and waterfront facilities on the adjacent ship repair facility, which could potentially be used. The repair facilities at Fitzroy Street also offer some potential, including wet berths, offices and covered and open storage.

The facilities and equipment make the Forgacs shipyards suited to roles such as block building and integration of lower complexity vessels.

Current capacity is either constrained by office and warehouse or by blast and paint facilities and the construction point. With investment, it is possible to relieve current painting and construction point capacity restrictions, but it would be relatively simple to increase capacity restricted by warehouse and office space by finding additional areas either on or off-site. Forgacs also operates an additional site at Cairncross in Queensland, which includes a 267 x 35 metre graving dock. This has potential for construction of a number of ship types including the larger supply ship. Plans for the redevelopment of this site have been produced. Forgacs Engineering also has several machine shop facilities in the area that could supplement the capabilities there.

The 95 metre Aurora Australis, the current supply vessel for the Australian Antarctic Division, was built and launched at the Tomago shipyard in 1990, and the same shipyard built the 41 metre Seafaris super yacht in 2006. While it only fitted out the first vessel after it was built in Italy, the Fitzroy Street shipyard built the other five of the six Huon class Minehunters (53 metres) from 1994 to 2003. At present, Forgacs is constructing 42 hull blocks for the Air Warfare Destroyer program, split between the Tomago and Fitzroy Street shipyards.

THE DEFENCE CAPABILITY PLAN 2012

To determine the current and potential capacity and capability of Australian shipyards, First Marine International initially reviewed the naval projects outlined in the 2009 White Paper and Defence Capability Plan 2012 and made an estimate of the types of warships that may be built for the Royal Australian Navy. While the icebreaker is not a Defence project, it is an Australian Government project and so has been included in this study as it is of relevance to the shipbuilding industry.

Once estimates had been made of the vessel types required in the future, the analysis then determined the capacity and capability of Australian shipyards to build those vessels, taking account of: vessel size; the inherent complexity of design; construction methods for those vessels; shipyard infrastructure, work practices and productivity.

The schedule for producing the projects in the Defence Capability Plan will have a significant influence on industry efficiency, the ability of the shipyards to deliver, and on project cost. Design lead times, the maturity of a ship's design at the start of construction, the viable rate of workforce build-up, and the further development of industry skills all need to be taken into account in the Defence Capability Plan schedule.

APPROACH TO CONSTRUCTION

Although some vessels in the Defence Capability Plan are most suited to construction in a single shipyard, it is possible that a dispersed construction plan would be adopted for the upcoming projects, similar to that currently applied to the Air Warfare Destroyer. Therefore each shipyard may contribute to a ship construction project in one of three ways: as a block builder, as a hull integrator, or as a single shipyard that builds blocks and integrates them.

The basic assumptions regarding the construction of the vessels in the Defence Capability Plan that have guided the approach to the capacity and skills analysis are as follows:

- For surface ships, the general approach to construction would be similar to Air Warfare Destroyer with limited grand blocking
- For submarines, the general approach would be similar to Collins
- There would be high levels of advanced outfitting on blocks
- The current production technology, and the processes and practices used to support production in the shipyards would remain the same as they are
- Shipyard productivity is based on current performance rather than potential performance
- Single shift working for 48 weeks a year
- 37.5 working hours per person week for 48 weeks a year, equating to 1,800 working hours per person per year.
- The ratio of engineering and support staff to production workers would be typical for naval construction, but varies by product type with more complex vessels requiring a high proportion of shipyard engineering staff.

The analysis considers the capacity of the shipyard companies to build each vessel type in the Defence Capability Plan in isolation, and does not evaluate the effects of the shipyards being involved in more than one project at a time, be it construction of new vessels or sustainment of the current fleet. Defence, being aware of the capabilities of each shipyard as outlined by this report, would have the role of managing the schedule of the naval projects so that the shipyards are not overloaded and can use their facilities and workforce efficiently.

First Marine International determined that the collective shipyard facilities assessed in this report have the capability to build each of the vessel types in the Defence Capability Plan. This is subject to a suitable launch position being developed for the large supply ship, for example through upgrading facilities at Adelaide, Melbourne or Newcastle, and assumes that some specialist equipment is purchased and that some aspects of production are subcontracted. Figure 8.5 provides a high level summary of the shipyards' capabilities.

SHIPYARD CAPACITY AND SKILLS

FIGURE 8.5: SUMMARY OF COMBINED ENTERPRISE FACILITIES

CAPACITY MODEL PARAMETER	TOTAL COMBINED ENTERPRISE FACILITIES AVAILABLE BY SHIP TYPE					
	FRIGATE	HEAVY LANDING CRAFT	SUBMARINE	OFFSHORE PATROL BOAT	SUPPLY SHIP	ICEBREAKER
Preparation and sub assembly area (m²)	11,729	11,729	11,729	11,729	11,729	11,729
Unit and blocking area (m²)	42,904	37,334	38,156	42,934	42,934	42,934
Blast and paint footprints	12	17	19	15	8	15
Current construction points	1.5	5	2	4	0	2
Potential construction points	2.5	9	2	5.5	1	4.5
Wet berth positions (exc. double banking)	4	15	8	10	3	10
Post-launch dry docking positions	1	6	2	3	0	2
Current covered warehouse area (m²)	19,381	19,381	19,381	19,381	19,381	19,381
Current office area (m²)	41,528	41,528	41,528	41,528	41,528	41,528

Existing launch facility dimensions indicate that at least one suitable building site currently exists for each vessel type, with the possible exception of the supply ship. The assumed dimensions and launch weight of the supply ship exceed the capacity of existing launch points and the suitability of two construction sites at Forgacs Newcastle requires further investigation. Accordingly, the supply ship design will need to consider the existing launch capabilities or alternatively, the capability of the launch point will need to be developed to suit the ship. There are other facilities in Australia which may be suitable, including the Common User Facility at either Osborne in South Australia or Henderson in Western Australia, or the graving dock at Cairncross, Brisbane.

The First Marine International analysis did not evaluate details about investments to increase the number of berths, blast and paint footprints, and unit and block assembly areas, although such expenditure is often required on naval projects. To do so would introduce too many possibly controversial and subjective variables into a clinical analysis of current capability. Exceptions to this are a relatively minor modification to the building berth in Williamstown and the re-commissioning of the side launch in Tomago. These have been considered in the potential capacity analysis to provide the ability to build frigates, icebreakers and the heavy landing craft in Williamstown and the supply ship in Tomago.

Cutting facilities for heavier plate may be required depending on the sites chosen to construct some vessels. Some sites lack warehouse and office space, particularly when an integration role is being considered although this could be overcome by creating more space onsite or sourcing local offsite space. Outfitting facilities such as electrical and electronic workshops and pipe manufacturing workshops limit capacity so such facilities would either need to be developed or the work subcontracted as is already being done by some shipyards.

The facilities examined only have a small number of post-launch dry-docking options. Depending on the build strategy employed, this may not be a problem as there is enough capacity within Australia as a whole to deal with any requirements.

In addition to absolute constraints, there are characteristics of the design and layout of a shipyard which determine how efficiently it could be used for a particular ship type. Some are flexible enough to produce vessels which may not be best suited to the facility. For example, a shipyard more suited to building smaller more complex vessels could take on blocks for larger, simpler vessels. This may be necessary to meet the needs of the Government shipbuilding program but the shipyards would not necessarily be operating at their most productive.

In addition to the sites included in the capacity analysis, there are other facilities available around the country which could support integration or other aspects of naval ship construction projects. Such sites would include Strategic Marine and the Common User Facility at Henderson, Western Australia, Incat in Tasmania, and others.

PRODUCTIVITY

Productivity has a significant influence on the capacity and capability of a shipyard. It affects the man-hours required to produce each vessel and the calendar time required to produce whole vessels and their interim products including blocks. The measure of shipyard productivity used in the study is man-hours per compensated gross tonne (see Annex C for an explanation of these terms). The man-hours used in the calculation are the hours of the total shipyard workforce, including direct, indirect and subcontractors. It is therefore a measure of the efficiency of the whole organisation.

Three aspects of shipyard productivity have been considered: core productivity, rate of improvement in core productivity, and first-of-class performance drop-off related to initial shipyard productivity in building a series of vessels. Core productivity is the best productivity a shipyard can achieve with its current production technology and a mature design. Shipyards do not always work at this level of productivity because first-of-class effects, interference between contracts, facilities development and other disruptions cause actual productivity to be lower. First-of-class performance drop-off is the degree to which actual productivity drops off when the shipyard builds a new first-of-class ship. Starting a new class of vessel generally causes a decline in shipyard productivity due to: immature and complex designs, ineffective planning, decreased worker efficiency, and lack of production optimisation. Low levels of shipyard experience with respect to the vessel type, less effective pre-production processes, low levels of design maturity, and complex vessels tend to result in higher first-of-class performance drop-offs.

Core productivity is influenced by the level of shipbuilding technology employed—the 'best practice rating', which is explained below—the skills of the workforce and the suitability of the product for the facilities. Figure 8.6 below shows the relationship between productivity and overall best practice rating by principal product type, which has been derived from First Marine International's global benchmarking studies. Shipyards that are lean and make effective use of their technology tend to fall on or below the appropriate trend line, while others tend to be above the line.

The best practice rating is determined through measurement using the First Marine International shipyard benchmarking system. The system contains 83 elements of shipbuilding technology grouped into 10 functional areas of shipbuilding practice which cover the pre-production,

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SHIPYARD CAPACITY AND SKILLS

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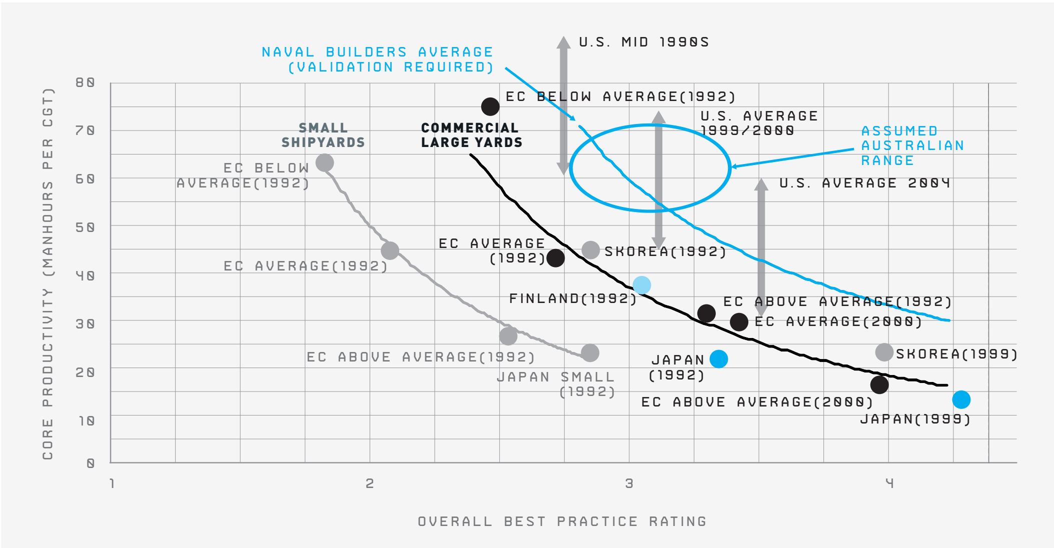
FIGURE 8.6: BEST PRACTICE AND PRODUCTIVITY



production and supporting processes. The benchmarking system describes five levels of best practice use in each element of each group. In broad terms, the levels correspond to the state of development of leading shipyards at different times over the last 30 years. Those shipyards that are less advanced remain at the level of technology of an earlier period. On the basis of interviews and inspections carried out during the survey, a "level of technology" mark is assigned to each element. The scores are aggregated, first, for the individual groups and, second, for the whole shipyard.

While the four Australian shipyards were not formally benchmarked to this level of detail as part of this study, First Marine International estimated the general level of technology applied during the shipyard visits. The estimated range of best practice rating for all the Australian shipyards is shown on the figure above. By considering this, the results of direct productivity calculations, their perception of the degree of leanness and the use of technology, a core productivity of between 60 and 70 man-hours per compensated gross tonne was assumed for the basis of the study, although there are examples of Australian shipyards achieving higher levels of productivity on some ship types.

The capacity model uses the average productivity achieved over a series as a basis for the estimate of capacity, and core productivity would not normally be achieved until at least the fourth vessel in a series with a stable design. As stated above, a number of factors influence the degree of performance drop off and therefore different degrees of first-of-class performance drop-off have been assumed for each shipyard depending on these factors. It has also been assumed that a continuous performance improvement program will result in core productivity improving at a rate of two per cent a year in all shipyards over the life of the series. The assumptions made have been averaged across the shipyards and vessels and are presented in Figure 8.7.

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FIGURE 8.7: PRODUCTIVITY ASSUMPTIONS

VESSEL TYPE	NUMBER IN SERIES	AVERAGE FIRST-OF-CLASS PERFORMANCE DROP-OFF ASSUMED	AVERAGE PRODUCTIVITY ON FIRST OF CLASS (HRS/CGT)	AVERAGE PRODUCTIVITY ASSUMED FOR TYPICAL SERIES LENGTH (HRS/CGT)
SUBMARINE	12	93%	135	62
FRIGATE	8	45%	96	69
OFFSHORE COMBATANT	20	45%	96	62
SUPPLY SHIP	2	40%	93	84
HEAVY LANDING CRAFT	6	33%	92	74
ICEBREAKER	1	50%	100	97

To summarise, requirements of Australian shipyard companies to achieve good levels of productivity in their work include:

- a skilled experienced workforce: efforts must be made to retain those workers with appropriate skills and experience in shipbuilding to act as a core group to drive productivity gains
- current technology allied with efficient work practices in the shipyards: shipyards must invest in infrastructure
- longer production runs: productivity is inevitably low when a new design is built in the shipyard but with a longer production run of at least four vessels and a stable design, productivity will reach core levels.

CURRENT WORKFORCE NUMBERS IN AUSTRALIAN SHIPYARDS

Information on the workforce at the four shipyards, relating to current numbers, proportion of employees with vocational qualifications, and levels of shipbuilding experience, be it commercial, naval or submarine, was gathered by First Marine International, aggregated for the combined enterprise and is presented in Figure 8.8. The numbers include the workforce at ASC North who are currently involved in submarine maintenance as they are likely to be involved in construction of the future submarines.

In addition to having the necessary qualifications and training, ideally a proportion of people in each skill group need to have experience with the type of vessel to be constructed. The proportion and the degree of experience required vary by skill group. For example engineers and production managers should have a high level of relevant experience, however very little vessel-specific experience is required in production support roles such as rigging or staging. The requirements that have been assumed in this study for the minimum number of years of experience and the minimum proportion of experienced people required in each skill group are shown in the second and third columns of Figure 8.8. They were developed by First Marine International in conjunction with experienced shipyard senior managers, and are considered to represent the minimum requirements for mature shipyards in a steady state with good productivity.

The numbers of people listed as being experienced have at least the numbers of years' experience listed in column three of the chart.

SHIPYARD CAPACITY AND SKILLS

FIGURE 8.8: WORKFORCE SIZE AND EXPERIENCE

	TOTAL WORKFORCE	MINIMUM NUMBER OF YEARS OF EXPERIENCE REQUIRED	MINIMUM PROPORTION EXPERIENCED PERSONNEL REQUIRED (%)	ACTUAL NUMBER OF EMPLOYEES WITH THE MINIMUM LENGTH OF EXPERIENCE REQUIRED	
				NAVAL SHIPBUILDING	SUBMARINE CONSTRUCTION
CEO and senior management	37	10	50%	21	10
Finance and accounting	82	2	25%	38	22
Sales and marketing, and communication	34	4	50%	14	7
Project management, commercial and contract management	152	8	50%	53	36
Purchasing and supply chain	100	5	25%	19	11
Estimating, planning, production and cost control	341	8	50%	87	36
Human resources and training	66	4	25%	16	1
General clerical	162	2	0%	43	63
Production management and supervisors	364	10	75%	125	87
Production engineering and performance improvement	46	5	50%	23	9
Engineering quality, test and commission, and metallurgy	154	10	75%	57	14
Facilities	79	4	25%	27	9
Engineering support—electrical	170	10	75%	56	30
Engineering support—hull	171	10	75%	52	34
Engineering support—mechanical	153	10	75%	56	37
Draftsmen	124	5	50%	6	1
Boilermakers	669	5	25%	95	39
Welders	347	2	25%	68	94
Electricians	204	5	25%	25	7
Mechanical fitters	226	5	25%	33	79
Pipe fitters	185	5	25%	46	15
Pipe welders	93	2	25%	14	22
Sheet metal, carpenters and insulation	138	4	0%	30	2
Painting	32	2	0%	14	1
Production support	270	2	0%	87	27
Totals	**4,399**			**1,105**	**693**

WORKFORCE PROFILE

First Marine International has found that, while the existing proportion of engineering employees across the shipyards can support the construction of all vessels in the Defence Capability Plan, the ratio varies considerably between shipyards and the assessment does not account for the additional workload associated with dispersed build strategies. There is, however, insufficient experience currently in the engineering workforce employed in the shipyards to build the submarines and larger surface combatants with a reasonable level of productivity.

Qualification levels were found to be appropriate across the shipyards and there are practically no instances of experienced employees that remain unqualified. All of the shipyards have good methods of understanding the skills requirements of their business and maintaining qualifications through a pertinent, rolling training program. The resulting levels of training vary between shipyards but have been found to be in line with or above international norms, which is as expected for an industry investing in building up its skills base.

The experience requirements for both submarines and surface ships was assessed, with the assumption that no other work is being carried out by the shipyards that reduces the availability of employees. The effect of a notional split of work across the ship construction industry between submarines and surface ships was examined assuming that the submarine project would benefit from the most experienced personnel. The assessment showed that in the majority of cases for both submarines and surface ships, there is not a sufficient proportion of appropriately experienced personnel for effective support of the inexperienced members of the group. The notable exceptions are:

- for submarines: mechanical fitters, welders, and finance and accounting
- for surface ships: senior management and finance and accounting.

It is only in this small set of skills groups that the level of experienced personnel exceeds the proportion regarded as the minimum for effective and efficient production. For many groups, current experience levels are insufficient to maintain the minimum capability described in workforce growth section, even though the absolute numbers may be above what is needed.

PRODUCTION WORKFORCE

Painting, sheet metal and joinery are generally subcontracted and the low capacity for these in terms of in-house employees is to be expected. This is also because current shipbuilding projects are just starting to reach the outfitting phase. Excluding these, the lowest capacity groups are electricians, boiler makers and pipe welders, shortages of which are supported by interviews with the shipyards.

In production, the capabilities of the shipyards are strong in pipe fabrication and reasonable for structural steelwork in the commercial sector. However, the experience levels of boiler makers and welders is less than ideal for both ships and submarines, and shipyards have reported difficulty in recruiting these trades. Steelwork capabilities for naval construction were also found to be a little weak, particularly for thin plate. Experience in these areas is improving through the naval shipbuilding projects currently underway in Australia.

There is little recent experience around the shipyards of the thick plate construction required for submarines and icebreakers. In fact, without the submarine-specific welding skills groups, less than one in 10 of the whole production workforce has any meaningful experience of submarine construction. The mechanical fitters are unusual in that over 40 per cent have submarine experience. This is driven by the fact that over 90 per cent of the mechanical fitters are employed by ASC and demonstrates that submarine experience is skewed towards outfit rather than steel—a consequence of the majority of the experience coming from Collins refit and repair work.

SHIPYARD CAPACITY AND SKILLS

Production experience in naval surface ships is better, with the average experience periods exceeding those felt necessary for effective production. From a capabilities viewpoint however, weaknesses have shown up for electrical work and particularly fibre reinforced plastic construction. Although the requirement for this is low in all sectors, its use is on the increase so a small capability, probably provided by subcontractors, may become important.

Capabilities for the installation of outfit are less than ideal although these vary somewhat between the shipyards. There are also indications of limited capability in the installation of specialist systems and electronics across the vessel types as this tends to be subcontracted to combat system equipment suppliers, which is sensible.

SHIPYARD ENGINEERING AND SUPPORT WORKFORCE

For all ship types in the Defence Capability Plan, there is a shortage of people in the shipyards with appropriate experience for the following skill sets:

- metallurgy and non destructive testing
- electrical engineering
- mechanical engineering
- structural arrangements.

Shipyards rely on subcontractors to complement their in-house capability in some of these skills sets. In contrast to the above, the engineering management group is highly experienced in commercial, naval and submarine construction. It seems that while shipyards are struggling to find experienced engineers throughout the disciplines, it has the benefit of experienced engineering leadership. Much of this experience has only been added since the Australian shipyards have started on the current ship construction projects.

There is also a lack of experienced production engineers and skills in design for production are scarce. Production engineering is a critical function and becomes even more so when a workforce lacks core experience and needs higher levels of production engineering support. This is a key area for the development of Australian staff as well as recruiting internationally. With sufficient production engineering skills in place early, it may also become possible to use this resource to train engineers in design for production and produce appropriate guidance for designers.

A key area where the capabilities of the workforce have been found to be less than ideal is in management, supervision and the organisation of shipyard work. Planning departments appear to be well resourced in terms of qualifications. However, the levels of experience for planning, steel and outfit scheduling, work preparation, and production control have been found to be too low for these critical roles.

For the commercial and administrative sectors, it has been found there is little relevant experience across all of the vessel types in purchasing and training. That said, the capabilities of the various purchasing departments were found to be reasonable. Finding personnel for recruitment and training is not considered to be a problem given the wide source of cross-sectorial labour resources available and the reasonably short periods of experience necessary for these skill sets.

MULTI-SKILLING

There are a number of multi-skilled employees in the workforce but the level of multi-skilling has not been developed to the extent achieved by leading international shipyards. Unions appear not to be blocking multi-skilling.

SUBCONTRACTORS

Although there are commonalties between the items subcontracted, the subcontracting philosophy varies between the shipyards. The proportion of work subcontracted varies from approximately one per cent to approximately 20 per cent. The list below shows the typical subcontracts for the group. The most commonly subcontracted items are at the top of the list:

- specialist non-destructive testing
- manufacture of outfit steel (ladders, pipe hangers, hatches, foundations etc)
- painting
- insulation
- specialist engineering analysis
- sheet metal work and ducting
- pipe manufacture
- plate and stiffener cutting and forming
- fabrication of structural sub-assemblies
- installation of electronics and weapons systems integration
- heavy lifts and movements
- fibre optic contentions
- assembly of junction boxes
- on-board machining.

MAXIMUM WORKFORCE SIZE

The maximum potential controllable workforce size was assessed for each shipyard and the results are shown in Figure 8.9. The following was considered:

- shipyard strategies and senior management opinions
- historical workforce size
- reported local labour market trends
- shipyard recruitment policies for growth.

The potential workforce size estimate has been used as the basis for determining potential shipyard capacity. It should be noted that only the core skills relating to building vessels in the Defence Capability Plan have been included. Employees involved in the following activities have been excluded:

- research and development
- provision of third-party training
- conceptual and first-of-class design work
- integrated logistics support outside normal shipbuilding contracts.

FIGURE 8.9: CURRENT AND POTENTIAL WORKFORCE SIZE

	CURRENT WORKFORCE	POTENTIAL WORKFORCE
Blue Collar	2,164	3,220
White Collar	2,235	2,980
Total	**4,399**	**6,200**

Comparing the maximum potential workforce size to the workload in the Defence Capability Plan, high-level analysis suggests that the peak workload as calculated by compensated gross tonnage in the Defence Capability Plan might be achieved by a ship construction industry workforce of more than 6,000 employees, which is of the same order as the 6,200 employees shown in the chart. However, the distribution of skills and other resource deficiencies means that the effective capacity would be much lower than this, and indicates that the ship construction industry will be unlikely to meet the delivery schedule set out in the current Defence Capability Plan. The shortfall will vary depending on the placement of vessel types around the shipyards and the phasing of the projects.

MINIMUM SIZE—MAINTAINING CAPABILITY

Through the Collins, ANZAC, Landing Helicopter Dock and Air Warfare Destroyer projects, the Australian Government has invested in developing the capabilities of the indigenous ship construction workforce. Although it has been higher in the past, currently there is a relatively low level of experience in warship construction but this is increasing as current naval projects progress.

If the vessels in the Defence Capability Plan are to be built in Australia at a level of productivity that is close to international naval norms, then the skill base needs to be maintained. There are some good international examples of where the erosion of skills between projects has resulted in some very significant cost overruns on subsequent naval projects. In Australia this recently occurred to the detriment of the Air Warfare Destroyer project.

In naval shipbuilding the first-of-class performance drop-off (that is, the lowering of productivity levels) that occurs at the start of a new series in a mature shipyard can be as high as 50 per cent. There are examples of this increasing to about 130 per cent in new shipyards with inexperienced personnel. Over a series of four typical frigates, this additional drop-off would cost between seven million and 10 million man-hours and there would be further costs associated with the schedule extension and possible technology transfer. Retaining the skills base helps to avoid these costs and reduce project durations.

As explained in the section on workforce numbers and profile, First Marine International assessed that for each skills group there are a minimum proportion of experienced personnel required to allow a ship to be constructed with a reasonable level of productivity. If shipyard workforces contract as the result of reduced workload, and then needs to ramp up again for a new projects, the experience levels need to be maintained at a level which can support the ramp up. Determining the minimum number is a complex problem as it depends on the period of the downturn, workforce attrition, the demographics of the labour pool, age profile, and succession planning. However, in broad terms the minimum level is considered to be the target number of people required multiplied by the minimum proportion of experience required. So if 500 electricians where required in the future and 25 per cent of them need experience with the product concerned, then it would be necessary to retain 125 experienced electricians through the trough. The assumptions made by First Marine International in the study regarding the proportion of experienced people required in each skill group are listed in Figure 8.8.

The future size of the ship construction industry depends on the work it will be required to undertake and the productivity achieved. Work on both new construction and warship support needs to be taken into account. First Marine International has calculated that a submarine construction project with an output of one boat every two years carried out at the same time as a frigate project with an output of one ship a year would employ about 3,200 people. A longer build duration for the frigates, at a keel interval of one ship every two years would reduce the numbers required. Depending on the schedule, a further 1,000 could be required to build other vessels in the Defence Capability Plan, and allowing another 800 for Collins maintenance, the overall ship construction industry would therefore need to employ about 5,000 people, with about 30 per cent engaged in submarine work. This total excludes people engaged in first-of-class design. Of course, the actual size of the workforce would depend on the phasing of the projects.

On the basis of a submarine workforce force of 1,500 people and a surface ships workforce of 3,500 people, the minimum number with the level of experience specified in Figure 8.8 is presented in Figure 8.10. To retain the necessary experience levels for a ramp up to 1,500 people in submarine construction and support, the total number of people involved in this sector cannot drop below 540. The equivalent number for surface shipbuilding, to support a ramp up to 3,500, is 1,130.

FIGURE 8.10: MINIMUM WORKFORCE SIZE

SKILLS GROUP (ABBREVIATED DESCRIPTION)	MINIMUM NUMBERS TO RETAIN EXPERIENCE BASE TO SUPPORT A WORKFORCE OF 5,000		
	SUBMARINE	SURFACE	COMBINED
Senior management	8	18	25
Finance and accounting	6	13	19
Sales, marketing and communication	3	7	10
Project management	38	72	109
Purchasing and supply chain	17	31	47
Estimating and planning	45	88	133
Human resources	9	22	31
General clerical	0	0	0
Production management	79	186	265
Production engineering	14	37	51
Quality, test and metallurgy	79	131	210
Facilities	2	4	6
Electrical engineers	23	47	70
Naval architects	20	32	52
Marine engineers	15	26	41
Draftsmen	13	23	36
Boiler makers	60	143	203
Welders	30	74	104
Electricians	26	92	118
Mechanical fitters	36	22	58
Pipe fitters	14	42	56
Pipe welders	7	21	28
Sheet metal and joiners	0	0	0
Painting	0	0	0
Production support	0	0	0
Total shipyard engineering	368	736	1,104
Total production	172	394	566
Total	**540**	**1,130**	**1,670**

Because of the higher level of experience required, a higher proportion of the engineering shipyard skills needs to be retained. For some production skills such as painting, which does not require a significant level of product-based experience, it would not be necessary to retain experienced people in these skill groups. The only reason to do so would be that it was extremely difficult to re-recruit people with these skills during a ramp up. As in welding, there may also be some key specialist skills in the other skills groups that would need to be maintained regardless and this may not be reflected in the distribution in Figure 8.10.

The best way to maintain experience levels is to employ people in a continuing shipbuilding project. If this is not available, other arrangements would have to be made. As there is an imbalance between engineering and production workforces in the minimum levels, if arrangements were made to employ all the production personnel on a ship construction project there would be an excess of about 60 per cent of the engineering people. These people would need to be employed on another project such as developing a new design. The imbalance means that it would only be possible to employ about 650 people effectively on a construction project which is equivalent to building about one frigate every four years or two small patrol boats a year. There would have to be a high level of flexibility within the engineering and production areas with about 30 per cent of the production workers in trades other than their principal trade.

To effectively retain the minimum surface ship engineering workforce on a ship construction project, the workforce would have to be increased to about 1,850 people, which is equivalent to about one frigate a year. There would also have to be a high degree of engineering workforce flexibility required.

WORKFORCE GROWTH RATE

The rate at which a shipyard workforce can grow has been considered for two circumstances:

- growth from current workforce size up to maximum workforce size
- growth from the theoretical minimum size required to maintain capability up to maximum workforce size.

The two circumstances vary because the level of experience that the workforce begins with is different in each case.

The numbers and proportion of experienced personnel that exist within a skills group are influenced by three factors:

- attrition rate
- growth rate
- the number of years of experience required.

Attrition reduces the absolute numbers of both experienced and inexperienced personnel. Attrition rates in international shipyards tend to be less than five per cent. Australian norms have been quoted at around 13 per cent for the manufacturing sector and in some shipyard individual rates have been found to be higher than this. Higher attrition in Australia may be to do with patterns of transience between the resources and manufacturing sectors or the fact that low unemployment means there is competition for people. Regardless of the reason, it is important for the shipyards in the combined enterprise to reduce attrition to retain experienced personnel.

It is important to understand that if a shipyard is to grow its workforce without suffering a significant productivity or capability penalty, a sustainable ratio of experience to inexperienced people needs to be maintained throughout the growth period. The minimum ratios assumed by First Marine International for this study are shown in Figure 8.8.

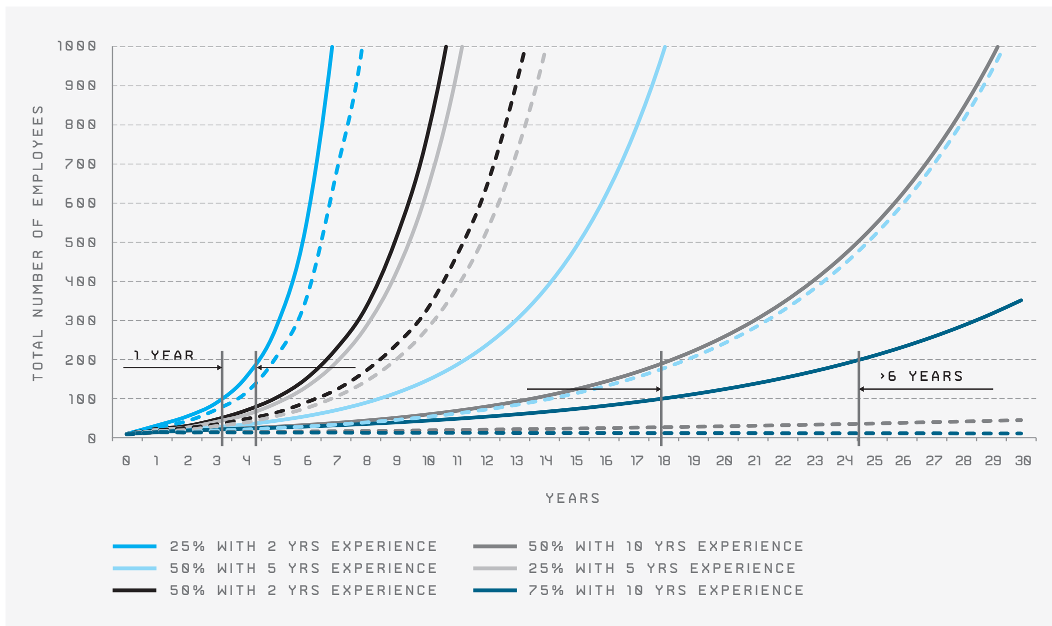
Assuming suitably qualified people are available in the labour pool, the maximum rate of growth therefore depends on the following:

- the minimum ratio of experienced to inexperienced personnel required in each skills group
- the time taken for inexperienced personnel to gain the required level of experience (the time for each skills group assumed in this study is shown in Figure 8.8)
- the number of experienced personnel already employed in each skills group
- the rate of attrition.

Maximum growth is achieved by maintaining the minimum proportion of experienced people through the growth period. Based on this assumption, Figure 8.11 shows the time taken to grow the workforce for each combination of the proportion of experienced people and the minimum years of experience required in Figure 8.8. These curves assume that the new workforce can be assimilated into the organisation at the rate shown, although in practice this may not be possible.

Two examples are shown on the chart. For a typical trade skills group, the proportion of people requiring relevant experience is 25 per cent and it takes two years to acquire the experience. This means that if there are 100 people employed, the minimum period to grow the workforce to 200 people will be one year. However, as 10 years' experience and a minimum proportion of skilled people of 75 per cent has been assumed for the production management and supervision, it would take five to six years to grow this group over the same range. The dotted curves shown on the chart represent the maximum growth rates allowing for

FIGURE 8.11: RELATIONSHIP BETWEEN EXPERIENCE REQUIREMENTS AND GROWTH



an attrition rate of 13 per cent a year. These curves demonstrate how much more difficult it is to grow an experienced workforce while experiencing this level of attrition. For the groups that require 75 per cent of the workforce to be experienced, it shows that growth is almost impossible to achieve without directly recruiting experienced personnel.

The curves assume that it is only possible to recruit qualified people who do not have the level of experience required and that there is always the minimum proportion of people in the workforce with experience. Clearly, if experienced people can be recruited or experience levels are higher at the outset, the rate of growth can be increased.

Figure 8.11 shows how difficult it is to sustain an experienced workforce while growing the workforce through the recruitment of qualified but inexperienced employees. For those skills groups identified previously as lacking enough experienced personnel, it may be necessary to recruit experienced personnel or accept a lower ratio of experienced employees during the growth phase and accept the corresponding drop in productivity that this will bring. As there is not much relevant submarine experience in the Australian labour pool, it is imperative that industry retains the experienced workforce it already has. It is also likely that achieving a sufficient number of experienced personnel will require international recruitment.

GROWTH FROM CURRENT WORKFORCE SIZE

All of the shipyards surveyed have demonstrated high rates of workforce growth over recent years. For many, this has been in response to the Air Warfare Destroyer and Landing Helicopter Dock projects workload. For some, the recent growth rates have been very high and there has been an associated loss of productivity.

The shipyards have reported a forward-looking growth rate at which they would expect to be able to recruit candidates from the local skills pool and absorb them into the current workforce. In each case, the rate was felt to be reasonable although not without some consequent loss of productivity. Without additional information regarding the external availability of skills in each area it has not been possible to temper the opinions of the shipyards with hard data.

The achievable growth rates reported by the shipyards vary but for ASC, BAE Systems and Forgacs the rates are all less than 25 per cent a year. Figure 8.11 demonstrates that in these instances maintaining the required proportions of experienced personnel is likely to be feasible except for the more demanding skills groups where 75 per cent of the employees are required to have 10 years experience or more. These groups are:

- production management and supervisors
- engineering quality, test and commission, and metallurgy
- engineering support—electrical
- engineering support—hull
- engineering support—mechanical.

The achievable growth rate reported by Austal is around 60 per cent a year. Although the situation for Austal is different because it would be returning to the workforce size of a few years ago, First Marine International felt that this rate of growth is perhaps optimistic and would result in low proportions of experience in the workforce.

Combining the predicted growth rates for the shipyards gives a combined rate of around 700 employees a year. This means that a ramp-up period of less than three years would be required to bring the shipyards up to their potential workforce capacity. However, a collective ramp-up of this nature may lead to competition in the labour markets and may reduce the speed at which the shipyards can employ qualified personnel, although the numbers required for the ship construction industry is small in comparison to other sectors.

Data relating to the availability of people working outside the ship construction industry who have the appropriate skills is not available. There have been some indications that legacy skills from the Collins program remain in-country. For those areas where the skills are at a premium—that is, the most specialised such as engineering or testing—it may be possible for the future submarine project to unearth latent skills. However, this is felt to be unlikely for the following reasons:

- the passage of time since Collins
- the global demand for similar skills
- ability to translate skills across sectors
- demand in shipbuilding means that those motivated to stay in the sector are likely to currently be employed in it.

GROWTH FROM MINIMUM CAPABILITY

The minimum size of workforce that is required to maintain capability within the combined enterprise is discussed in detail in workforce growth rate sub-section. The growth rate that can realistically move from this minimum size to the maximum workforce size across the shipyards is not subject to the constraints set out in Figure 8.11, as there is no need to further develop the experience within the workforce, only the inexperienced but qualified workers. Therefore, the only limits to growth are the availability of qualified candidates and the speed at which a shipyard can assimilate new, qualified employees into its workforce. The high rates at which Australian shipyards have grown in recent history demonstrates the upper end of what may be achievable, although this resulted in a low level of productivity for a long period.

The combined industry growth rate of 700 people a year would lead to a ramp-up period of over six years to go from the minimum to maximum workforce size. It is felt that this could be improved upon given the level of experience in the core workforces and that the ramp-up could realistically be achieved at a growth rate of around 40 per cent a year. This would bring the ramp-up period down to between three and four years.

SUMMARY

The assessment by First Marine International has shown that, on a project by project basis, the four main shipyards have the capacity to build the ships in the 2012 Defence Capability Plan apart from the large supply ships, and with some investment into launch facilities, could construct those as well. Similarly, in general, the current shipyard workforce in Australia has excellent skills and good submarine and shipbuilding knowledge in some skills groups. However, experience levels are low when compared to international norms and numbers are limited in some groups.

The submarine skills base will need to be expanded to construct new submarines and maintain the existing fleet at the same time. As new construction will not begin for some years, arrangements will need to be made to maintain and further develop the skills base through the interim period. This may require experienced people to be recruited into a few key roles at the right time. The surface ship skills base is being expanded through the current Air Warfare Destroyer and Landing Helicopter Dock projects and perhaps some of those skills and experience can be later applied to the future submarine project. As the skills pool is shared between surface ships and submarines then transferring skills to one project could be detrimental to the others. This and the interaction between projects must be carefully managed by the Defence Materiel Organisation.

FACTORS LIMITING MAXIMUM SHIPYARD CAPACITY

When viewed as whole, and taking the current proposed acquisition schedule of the 2012 Defence Capability Plan into account, the situation is somewhat different. As it currently stands,

SHIPYARD CAPACITY AND SKILLS

the requirements of the Defence Capability Plan present a significant challenge for the ship construction industry. Based on a high-level analysis of the requirements, the phasing of the current plan appears to create high peak demands and the workload is not well balanced against shipyard capacity or the requirement to develop the industry's skills base. There appears to be bottlenecks, principally in skills but also in facilities, which means that there is unlikely to be sufficient capacity to deliver all the vessels to the schedule envisaged.

In addition to aspects such as construction points, crane capacity and buildings, the number and the skills of the workforce and shipyard processes and practices also limit capacity. With the exception of submarine construction, where capacity is limited by the berth cycle time (that is, the time taken to consolidate the submarine in the workshop), in the majority of scenarios considered by First Marine International, it is the availability of people with appropriate skills and experience that is the limiting factor.

Improving shipyard productivity will reduce the number of people required to deliver the output and alleviate the skills deficit to a large extent. Raising the level of productivity will require processes and practices within the shipbuilding enterprise, government and industry, to be improved and skill levels to be increased. Continuity of work, ideally at a reasonably steady level, will also be necessary. The project dates envisaged in the Defence Capability Plan would need to be changed to achieve a reasonably steady workload across the ship construction industry. Design maturity and the reduction of work content through designing for production will also be important. As has already been recognised by the Defence Materiel Organisation, the commercial environment created by contracting arrangements also needs to promote performance improvement.

Competition can drive performance improvement but it can restrict communication and sharing of best practices, learning, and resources. It can also result in project-focused, short-term horizons which inhibit longer-term investment in people and facilities and make an industry less attractive to work in. As resources are limited and the ship construction industry needs to unite to build the skills base and construct the vessels in the Defence Capability Plan, First Marine International recommend that the Defence Materiel Organisation should consider alternative strategies that promote development through cooperation. An enterprise-wide cooperation strategy that includes members of the ship construction industry, the supply chain and the Defence Materiel Organisation, will assist in improving performance.

Although manufacturing hull blocks at a number of sites and integrating elsewhere may ultimately be required to balance capacities, in general a dispersed construction program leads to lower levels of productivity. Constructing vessels of the same class simultaneously in different shipyards increases capacity but, due to the existence of multiple learning curves and the additional coordination required, overall productivity is reduced.

Electricians are the trade that most often limits current capacity across the shipyards. Importantly, there are also some key shipyard engineering skills, such as production management, production engineering, project management and planning, in which increased levels of skills and experience are required. Potential capacity is based on the shipyards' opinion of the number of people that could be recruited. Clearly capacity would be higher if it were possible to employ more people. The extended use of on and off-site subcontractors would also increase the capacity.

In terms of the facilities and the skills and experience of the workforce, some shipyards are better suited to certain vessel types or roles within a project. Rationalising the types of ships to be built for the Royal Australia Navy, adjusting the phasing of the Defence Capability Plan acquisition schedule, and allocating work between the companies to take account of available capacity and workforce will have a significant influence on shipyard use and therefore productivity and capacity.

SUGGESTIONS

The acquisition schedule laid out in the Defence Capability Plan 2012 is unworkable. The current plan sees work in the Australian shipyards almost cease in the latter half of this decade before it has to ramp up substantially as the construction of the future submarine and the offshore combatant vessels begin in the early 2020s, and the future frigates start a few years later. If nothing is done, the shipyards will most likely lose their workforce, they will not invest in infrastructure or update equipment at the shipyards, and may even close.

First Marine International suggest that any considerations regarding changes to the Defence Capability Plan should include the following:

- → The acquisition schedule must be smoothed out to avoid leaving shipyards underused. The ability of the shipyards to retain their workforce that has been built up through their work on the Air Warfare Destroyer, Landing Helicopter Dock ships and Cape class projects depends on having a predictable schedule.
- → The Defence Capability Plan must allow time for production engineering of projects. The shipbuilding industry must work with Defence to develop sensible construction timelines, rather than try to conform to overly ambitious schedules.
- → Stability in the acquisition schedule would allow the shipyards time to develop their facilities and grow their workforce, skills and experience in preparation for the start of new construction projects.

First Marine International made the following recommendations:

- → Technology transfer programs should be used to maintain and develop submarine skills. If possible, this could include international placements for shipyard engineering personnel before the future submarine project starts.
- → Succession planning should be developed for key shipyard production and engineering skills.
- → Skills should be built up on the current and future complex surface ship projects and transferred to the future submarine project.
- → Personnel should be seconded to Collins support to build submarine skills.
- → Workforce skills that take time to grow should be identified and prioritised for early development.

To aid the skills plan, a nationwide skills matrix should be developed and maintained. Although this may appear to be a substantial undertaking, such matrices are already used in the shipyards so it would only be necessary to standardise them and combine the information at a national level. This should be coordinated by the Defence Materiel Organisation.

Clearly, a systematic approach is required to address the issues with the Defence Capability Plan, Defence and a ship construction industry. It may also be helpful when considering construction scenarios to extend the work done by First Marine International to produce an index or matrix that quantifies the degree of suitability of each shipyard to construct particular vessel or block types. This would take both facilities and workforce characteristics into account.

09

THE AUSTRALIAN WORKFORCE

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THE AUSTRALIAN WORKFORCE
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THIS SECTION DESCRIBES THE WORKFORCE ENVIRONMENT IN WHICH NAVAL SHIPBUILDING OPERATES IN AUSTRALIA. THIS COVERS THE BROADER AUSTRALIAN MANUFACTURING SECTOR, CYCLES IN SHIPBUILDING ACTIVITY, COMPETITION FOR SKILLED WORKERS, PROMOTION OF TECHNICAL CAREERS IN SCHOOLS, AND OPTIONS TO RECRUIT OVERSEAS WORKERS. THIS SECTION ALSO COVERS SOME OF THE BROADER ACTIVITIES OF DEFENCE TO PROMOTE SKILLS DEVELOPMENT AND CAREERS IN ENGINEERING.

AUSTRALIAN MANUFACTURING INDUSTRY

Manufacturing is important to Australia. It makes a large, direct contribution to national output, employment, investment and innovation. The manufacturing sector produces 29 per cent of exports and contributes eight per cent directly to Australia's Gross Domestic Product, and more indirectly through connections with other sectors of the economy.

Manufacturing employs close to one million people, and more than half of these are employed by small to medium manufacturing enterprises. In comparison, the mining and resources sector employs 275,000 people (Australian Bureau of Statistics, 6291). There are 50,000 small manufacturing firms that employ 200 or fewer workers. Manufacturing accounted for 35 per cent of all traditional apprenticeship completions in 2009.

The size of the manufacturing workforce has been declining for decades. Since the global financial crisis the sector has lost over 100,000 workers and projections indicate that at least another 85,000 may go (Smarter Manufacturing, p.12). Overall, productivity growth is slow.

While Australian manufacturing cannot compete with the low paid workforce overseas, what strengthens the sector is an emphasis on advanced manufacturing. Naval shipbuilding is one such area where the destroyers and submarines are some of the most advanced manufacturing programs undertaken in Australia.

SHIPBUILDING CYCLES

Since World War II, Australian naval shipbuilding has gone through three cycles. After the war, the first major warship projects in Australia were the Daring and River class destroyers built at the Williamstown Naval Dockyard in Melbourne and Cockatoo Island Dockyard in Sydney in the 1950s and early 1960s. These projects ended up with large cost overruns: the Daring class ships were twice as expensive as the same ships built in Britain, and the River class ships were three times over budget. They were late as well.

It was 15 years before another large warship was built in Australia. In 1985, the keel was laid for HMAS *Melbourne*, one of the two US Navy FFG–7 class ships built in Victoria. *Melbourne* was accepted in 1992 and the second, *Newcastle*, in 1994. The Australian Frigate Project budget was $830 million (1983 prices, about $2.3 billion today).

Building two frigates was the critical start the Melbourne shipyard needed to make the ANZAC project the success it was. Had the shipyard not got that work, construction of the ANZAC ships would have run into all the same cold start problems seen on other projects. Such instability at the beginning of that program would have taken several years to work through and in such circumstances the project would not have earned its good reputation. Construction of the ANZAC ships commenced at what is now the BAE shipyard in 1992. Ten ships were built, eight for Australia, two for New Zealand. *ANZAC* was delivered in 1996, and the last ship, *Perth*, in 2006.

At the same time as the ANZAC frigates were being built, Australia was also constructing the Collins class submarines, the first time the country had ever built such a vessel. Six submarines were constructed in the new ASC shipyard in Adelaide between 1990 and 2003, except two sections of the first submarine manufactured in Kockums' shipyard in Malmo, Sweden.

The third cycle is now underway with the construction of the Air Warfare Destroyers and Landing Helicopter Dock amphibious ships, and the Cape class patrol boats built by Austal for Australian Customs and Border Protection. Using a modular construction program, the blocks for the three Air Warfare Destroyers are being built in shipyards located in Adelaide, Melbourne and Newcastle, employing a production workforce of over 1,800 people. Over 400 people in Adelaide and Sydney are working on developing and integrating the combat system. Melbourne is also home to the Landing Helicopter Dock project, where the superstructure, combat and communication systems will be integrated to the two main hulls being constructed in Spain. There were early production issues on the Air Warfare Destroyer blocks, with respect to dimensional control and welding heat distortion. These problems were solved as people became more familiar with ship construction techniques, and with the introduction of some very experienced shipbuilders and production supervisors from the United States and United Kingdom. Austal are building eight Customs patrol boats at their facility in Henderson, WA. These are a development of the Armidale class patrol boat which Austal built for the Royal Australian Navy between 2004 and 2007.

ATTRACTING SKILLED PEOPLE TO SHIPBUILDING

The previous three sections of this report emphasised the importance of retaining skilled, experienced people. Beyond the specific reasons to do this that they describe, an overarching question is whether shipbuilding is an attractive career.

Through the cycles of activity described above, many people are denied the option to pursue a life–long shipbuilding career because of lack of opportunity. As previously mentioned, there is a tendency for people who leave the shipbuilding industry in the down periods, not to return.

The consensus across people involved is that shipbuilding is a highly desirable career: it deals with the science and engineering of new and sophisticated technology, and the construction of large complex machines. In talking to people in and around shipyards, what is very clear is a passion for the challenge and reward of building warships. When the Air Warfare Destroyer project started in Adelaide in 2006, there were 20 people in the headquarters. Two years later, there were more than 300, with many moving from interstate and overseas. One reason given was because Air Warfare Destroyer is one of the most prominent warship projects happening globally.

One of the attractions of a shipbuilding career is city living—ships are built by the sea. Project management and engineering operations are done near the shipyard or in another capital city. The Air Warfare Destroyer project's main operations are in Adelaide, Melbourne, Sydney and Newcastle. The Landing Helicopter Dock project is based mainly in Melbourne, Austal's Australian operations are at Henderson near Perth. These are population centres and attractive locations for people who are looking to move from outback mining towns for family and lifestyle reasons.

COMPETITION FOR SKILLED PEOPLE

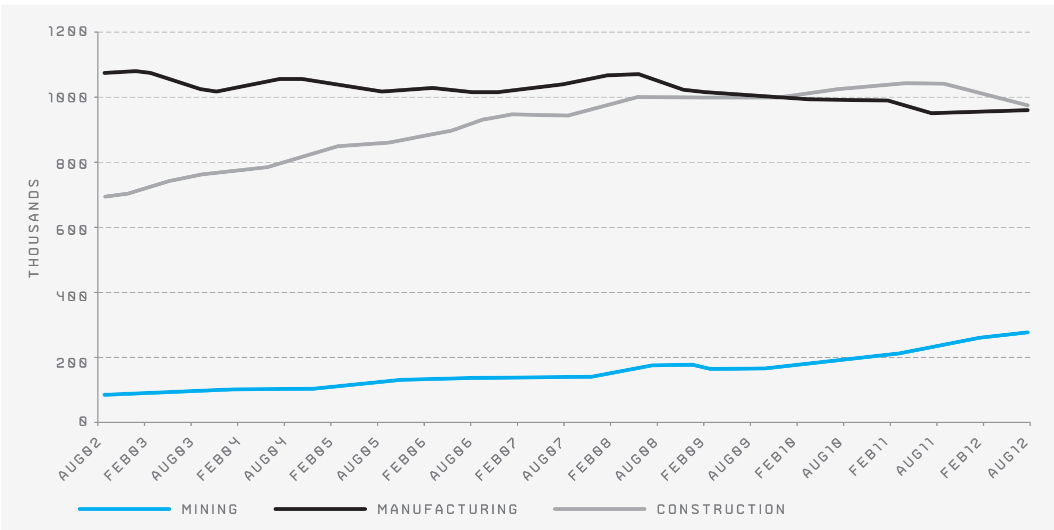
There is considerable commentary about future competition for skilled workers in Australia. Studies by the Defence Materiel Organisation, Defence Science and Technology Organisation, RAND, Skills Australia and others have examined the supply and demand for certain skills across broad elements of the defence sector such as systems integration, through to narrower domains such as future submarine. Research done for this study by First Marine International examined shipyard workforce supply and demand, including past experience in building up workforces for new projects. None say the competition for workers is disabling.

According to the latest Australian Bureau of Statistics data (August 2012), the total Australian workforce numbers just over 11,466,000 people. Of those sectors concerned with production, manufacturing and construction each account for close to one million workers. The mining and resources sector provides employment for 275,000 workers. The trends in these sectors are shown in the following graph.

Research for this study shows there are about 4,000 people working on naval shipbuilding in Australia today. This is less than 0.05 per cent of the Australian workforce of 11 million people, and 0.5 per cent of Australia's manufacturing workforce of 960,400 people. Broken down into very specific engineering and systems skill sets, the proportion is higher, but overall naval shipbuilding is not an industry dominant employer of skilled workers.

The Skills Australia report *Building Australia's Defence Supply Capabilities* was published in September 2012 and indicated there was competition for skills from the resources sector, which was able to pay high wages for electrical and mechanical engineers. The report also noted that electricians would be in short supply over the next decade, and that demand for construction skills in the resources sector would peak well before the end of the decade, before those skills might be required in naval shipbuilding. Anecdotal evidence provided to Skills Australia during consultations for its report suggested that resource sector workers spent on average two to three years in the sector and increasingly even shorter times. It seems that recruitment of these workers is an opportunity for defence industry.

FIGURE 9.1: EMPLOYMENT PER ECONOMIC SECTOR OVER THE LAST 10 YEARS



Source: Australian Bureau of Statistics, 6291

Examining worst case demand for a naval shipbuilding workforce, the peak rises to about 10,000 people. This would be the demand only if, firstly, nothing was done to level off the peak workload at the end of the decade, and secondly, nothing was done to improve low levels of productivity. Removing sharp peaks in workload is something Defence can do in planning future shipbuilding projects. Based on First Marine International's benchmarking of Australian shipyard productivity compared to world's best practice, continuing work and ensuing productivity gains mean the workforce could be smaller than today.

The outcome portrayed to this study is a national naval shipbuilding industry whose workforce needs to develop particular skills, increase experience levels, adapt to new projects and improve productivity, but does not need to appreciably grow in size.

Competition for skilled workers was discussed at the expert industry panel, where all the major companies involved in shipbuilding, unions and industry organisations were represented. The consensus was that the numbers of people potentially needed for future shipbuilding programs is something that can be managed by the companies—it is something they have done before. Clearly the challenge is made easier if workloads are forecast well ahead of time, and the time allowed then to ramp up is practical.

The research by First Marine International also showed that Australian shipyards are actually good at building up workforces, the result of having to do it regularly. First Marine International found that shipyards are reasonably confident they could further raise capacity and saw no major risk with the sort of workforce numbers they might need to recruit in their regions.

ATTRACTING YOUNG AUSTRALIANS TO SHIPBUILDING

Nation building enterprises such as the Snowy Mountains Hydro-electric Scheme, the National Broadband Network, and future submarines are projects that inspire the next generation of scientists and engineers. Building a submarine offers great challenge and reward to the people involved, most of who are currently in school.

Promoting science and engineering studies to students is important. Through the Industry Skilling Program Enhancement scheme, Defence supports initiatives that encourage high school students to study science, technology, engineering and mathematics—known as STEM subjects:

- the Defence Materiel Organisation sponsors the Re-engineering Australia Foundation (REA) F1 in Schools Technology Challenge, which provides opportunities for school students to develop skills and build an interest in engineering and manufacturing through hands-on team activities. The aim is to raise student awareness of engineering and defence industry careers. A submarine challenge could be introduced into this framework.
- the Defence Materiel Organisation also funds three school pathways programs: the Advanced Technology School Pathways Program in South Australia, the Marine Industry School Pathways Program in Western Australia, and the Advanced Manufacturing School Pathways Program in the Hunter region of New South Wales. These programs introduce students to skills used in defence industry and aim to increase the number of students studying science, technology, engineering and mathematics.

Also helping to promote careers in the science and technology sector are initiatives like the Maritime High School Program in South Australia at the Le Fevre High School. Around 150 students undertake vocational training that provides them with an insight to maritime work and trade career pathways. Scientific courses have also been developed in ship design, electronics, radar, GPS and navigation technologies. There is a similar program at the Aviation High School in Clayfield, Queensland.

Promoting science, technology, engineering and mathematics subjects and pathways to defence industry careers develops the flow of young people into naval shipbuilding. There is a range of state and national programs that are doing well in promoting these outcomes.

DEFENCE INDUSTRY SPONSORSHIP

Through the Defence Industry Policy Statement 2010, Defence committed $446 million to boosting the competitiveness of, and provide opportunities for, defence industry over the next 10 years. A large part of that funding is for industry assistance programs to improve skills, increase the workforce by attracting students to defence industry careers, and encouraging high school students to study science, technology, engineering and mathematics.

Defence will invest about $90 million by 2016 in the Skilling Australia's Defence Industry (SADI) program. SADI provides companies with funding on a reimbursement basis, for completed, pre-approved skilling activities across a broad range of technical and professional areas. Funding priority is given to proposals with a direct impact on the health of a Defence Priority Industry Capability.

All of the principal shipbuilding companies have used SADI to develop skills. In 2005, ASC, BAE Systems, Saab Systems and University of South Australia developed a proposal to develop and deliver of a Masters of Engineering, Military Systems Integration. This submission was successful, with SADI funds granted to develop the course as a joint industry/academic effort. Industry committed to send 54 students to the first three courses for the three-year part-time program.

In the shipyards, BAE used SADI funds to sponsor about 50 apprentices over the past four years—23 in heavy metal fabrication—and put 40 people through warship familiarisation training in preparation for the Air Warfare Destroyer and Landing Helicopter Dock projects. ASC has used SADI funding to place students on project management and systems integration courses, for diesel training, and for apprentice supervision. In the last four years, nearly 400 Forgacs workers have benefited from training sponsored by SADI, and another 100 are enrolled in SADI programs in the first half of 2013. More than 150 people at Austal have been helped with similar programs.

Members of the expert industry panel were very complimentary of the SADI program and there is strong support for it to continue.

SKILLED MIGRATION PROGRAMS

During the study, the team was asked to review migration and visa arrangements to see if these could assist with the plan.

Since the late 1990s, Australia has sought to build its workforce using a skilled migration program. Under this initiative, companies can sponsor skilled workers from overseas to fill positions they have been unable to fill through training or recruiting. Employees come in under either a temporary (Subclass 457 for up to four years) or permanent visa. Only certain occupations can be sponsored for entry, and virtually all the professional and trade occupations relating to shipbuilding are included.

The Employer Nomination Scheme (Subclass 186 visas) is for those skilled workers coming to Australia for the first time and who plan to stay for more than four years. This visa also caters for workers who come to Australia on Subclass 457 visas, and who work for two years before being offered a permanent position by their employer.

Labour agreements form a subset of the Employer Nomination Scheme. They are formal arrangements between an employer and the Commonwealth, effective for two to three years, and allow an agreed number of overseas skilled workers to be recruited for specific skilled positions. Companies might consider using these agreements when the required skills are not listed on the Skilled Occupation List or covered by the Australian and New Zealand Standard Classification of Occupations.

In 2011–12, 68 per cent of total migration numbers entered Australia via the Skilled Migration Program, or about 126,500 people. Over the same period, the number entering under a temporary visa totalled 68,310. Relating to shipbuilding, manufacturing brought in just over 4,000 people, while almost 5,000 entered in the professional, scientific and technical category. In comparison, construction brought in over 9,000, health care and social assistance almost 8,000, and information media and telecommunications around 7,500. Over 46,500 permanent workers were brought in through the employer sponsor category. Just over 30,000 were part of an employer nomination scheme and labour agreements.

The four main naval shipbuilding companies do not use skilled migration programs to build up their capacity. A small number of people are brought in to provide very specialist skills and shipbuilding experience, such as those with experience in building US Navy destroyers equipped with the Aegis Combat Systems, shipbuilding dimensional control specialists and experienced shipyard production supervisors.

The companies represented on the expert industry panel said they were able to work within current skilled migration programs and had no plans to expand foreign worker recruitment.


ARMADILLO

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BUILDING THE SKILLS

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BUILDING THE SKILLS
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THIS SECTION OUTLINES ACTIONS TO BUILD THE SKILLS TO BUILD THE FUTURE SUBMARINES IN AUSTRALIA. THE ACTIONS COVER ALL NAVAL SHIPBUILDING ACTIVITIES THAT COME BEFORE THE START OF THE FUTURE SUBMARINE PROJECT BECAUSE HOW WELL WE EXECUTE THAT PROJECT IS DEPENDENT UPON HOW WELL DEFENCE AND INDUSTRY ARE PREPARED ON DAY ONE.

The actions proposed are described as principles rather than specific tasks because of the complexity of the entire scheme of naval shipbuilding projects. Each project involves an array of variables that can result in different execution plans, and every project is different. Furthermore, plans change and projects encounter problems, so the situation is continually changing. This dynamic requires guiding principles and active management.

BUILDING INDIVIDUAL SKILLS

The analysis done for this study and in earlier work such as the 2011 RAND report, shows that Australia educates and trains people with the foundation skills needed to build the future submarines. Universities and other higher education institutions provide the engineering, computing science, accounting, business, law and other degrees required in a shipbuilding project. Vocational training organisations and apprenticeships deliver the welders, fitters, electricians, and other trade skills required to build warships.

For the Future Submarine Program, the main area of skill difference between the four options is in the functional design of the submarine. Obviously, military off–the–shelf options do not require the level of skilled design effort that the other options need, but some design skills will be necessary. The particular foundation skill affected is naval architects and all advice to this study is that Australia has the education programs required.

For the Future Submarine Industry Skills Plan, the questions are whether there are enough qualified people and whether experience levels are adequate.

BUILDING INDUSTRY SKILLS

Workforce size

How many people and the specific skills that are needed to build the future submarines is not something that can be precisely calculated at this time. There are many variables that affect this result.

The four options being examined for the future submarine program will require different skill sets, and key features of the plan to execute the project will also vary the number. As described above, a new type of submarine will require many more engineers to complete the functional design, which will also delay the start of manufacturing, hence build-up of the production workforce. If the new design is bigger than existing conventional submarine designs, which is the general opinion, then more production workers, or time, will be required to build the boats.

When the first submarine is required will greatly change the workforce time profile, and that date is dependent upon several variables: improving Collins submarine reliability and availability, the actual life of type of the Collins, whether money is invested to extend that service life and by how much, as well as strategic considerations about the capability of the submarine force. In addition to setting the timing for build–up of the production workforce, the sooner the first submarine is required the higher the peak design and production engineering workforce that will be needed to prepare the shipyards and construction data and materials.

The keel interval of the build project will affect the average size the workforce. A slower project with longer keel intervals requires fewer people, a higher cadence will require a larger workforce.

What the analysis in sections 6 to 8 show is that the current shipbuilding workforce is around 4,000 people. As detailed in section 8 on ship construction, the number of people in shipyards could reduce to about 1,700 to preserve the minimum core of skilled and experienced people. The workforce would then be able to grow at a realistic rate of not more than 25 per cent a year, or about 700 people a year. In this calculation, it would take up to six years to bring the shipyard workforces up to their maximum capacity—which is not the capacity required to deliver the Future Submarine Program.

The analysis describes the many disadvantages and risks of such a theoretical approach, such as lower productivity meaning larger workforces are required, adding cost. High attrition rates mean that for skill groups that require 75 per cent of the workforce to be experienced, growth is almost impossible to achieve without directly recruiting experienced personnel from overseas. Given all the challenges a new submarine project presents, taking a risk on substantial workforce downsizing just before the start does not seem prudent. The realisation of just a few risks in building up the skilled workforce could delay the project by many years.

The best way to have sufficient skilled people to build the future submarines is to retain the entire existing workforce, where everyone is gaining experience even if numbers are not yet adequate. In practice, workloads and workforces within existing projects change and new projects would not preserve precisely every job. What is needed are future shipbuilding plans that are developed with this principle in mind. Where possible, the scheme of all current and new projects leading up to future submarine should be arranged where practical to preserve the current skilled workforce. Also, future submarine project schedules should be coordinated with that plan so the different skill groups can move across without a gap wherever practical.

Proficiency

As described at the beginning of this report, the third dimension to skill is proficiency: the combination of knowing what to do (effectiveness) and using the least resource (efficiency). Given the right number of people with the right education and training, the challenge is then to turn them into a team proficient in all aspects of a submarine project. That requires training, professional development, mentoring and sheer practice.

All the naval shipbuilding projects preceding future submarine are an opportunity to develop these skills in Australia. Working on non–submarine shipbuilding projects provides good exposure to the various tasks undertaken, tools and processes used, interdependencies with other work groups, the sequence of events and schedules, mistakes made and breakthrough results. The action required is for Defence to formulate those other project plans with these benefits to the future submarine project in mind. DeakinPrime also noted the benefits of this 'whole of force' approach in their Future Submarine Training Feasibility Study (DeakinPrime 2011, p2–3).

Of course there are particular tasks, tools and processes in a submarine project not seen in surface ship projects. One small action would be to sponsor training programs for people likely to be involved in the project in tools and techniques specific to a submarine project. The problem is that until the final companies are chosen, the precise tool set and approach to design will not be known. That does not make such training worthless, and while some trained people will be lost, it will still be of value.

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BUILDING THE SKILLS
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Another option would be to carefully select Australians who are almost certain to be working on the project within Defence or industry and to sponsor them on two year secondments to a range of active submarine design offices and construction shipyards. For example, to Electric Boat in the USA, BAE Systems in the UK, Navantia in Spain, HDW in Germany, and so on. The destination needs no link nor infers any link to ultimate decisions on design, designer or builders for the future submarine. The immersion in active projects is what is important.

The Skilling Australia's Defence Industry scheme has been successful in helping companies involved in shipbuilding to improve the skills of select people. That should continue. One adjustment would be for the Defence Materiel Organisation to develop the nation-wide skills matrix discussed in section 8 and use that to target specific skills gaps for sponsorship.

Ultimately, it will not be possible to prepare everyone to an optimum level of skill. Identifying skills gaps in the available workforce will be a critical task for the directors of the future submarine project.

Productivity is also important. In systems development, the labour effort is proportionally much smaller than in ship construction, but efficiencies can be achieved through professional development of people and sensible investment in better tools and test facilities. Though very difficult to measure in simple quantifiable terms, productivity in systems development in Australia seems reasonable. This result is due to a consistent work program for the few companies that do this work, and because they often benefit from the backing of their multinational parent companies. Those global companies invest large sums of money to improve their tools and processes based on feedback from a great number of global projects and as a result the Australian subsidiaries benefit from this reach back.

In ship construction, productivity is currently low in Australia because the shipyards are rebuilding their capability. Continuing with the current routine measurement of actual productivity in shipbuilding projects is important, and the shipyards have to set and achieve improvement targets. Without improving actual productivity to world's best practice, and then continuing to steadily improve core productivity, the required competitiveness of Australia industry will not be achieved. This is a commitment the shipbuilding companies need to make.

THE APPROACH

The work in developing the Future Submarine industry Skills Plan showed that the most important action is to organise all the projects leading up to future submarine so they retain as much of the skilled workforce as is reasonably possible, and provide an opportunity to build skill in terms of proficiency and experience. New foundation education and training courses are not required. Recruiting people before work starts is also not necessary because there is a respectable core of skilled people already in Australia who, with careful planning, can help grow the workforce. Some targeted recruiting of skilled people by companies will be required for some submarine specific skills, especially where extensive experience, in some cases 10 years or more, is required. This issue was also highlighted in the recent Skills Australia report which made note that 'ebbs and flows in procurement activity inhibit the ability of organisations in Defence industry to grow, attract and retain specialist skills'.

The remaining elements of this section deal with key principles to be applied to planning naval shipbuilding projects with the objective of best preparing Australian industry for the challenges of the future submarine project. As discussed at the beginning of the report, the plan is not about job protection or industry subsidies, it is about the skills and industrial strength that are fundamental to successful naval shipbuilding projects which underpin our national security.

Planning naval shipbuilding projects

The Future Submarine Industry Skills Plan was commissioned because the current schedule for future naval projects will cause serious skill problems for Navy, Defence, government and industry. Shipbuilding activity was forecast to decline to almost zero in about 2017, followed by a large rise around 2020. The current schedule would result in the departure of most of the skilled and experienced people from the industry, and create major problems as industry tried to rebuild to execute new projects, which will result in higher costs and project delays

The problems seen with the current shipbuilding projects in the last few years are the direct result of having to rebuild Australian shipbuilding, given its decline after the ANZAC and Collins projects. As described in section 3, shipbuilding projects that start up after any such decline cost more: facilities have to be built or upgraded, and workers have to be recruited and trained. This also leads to schedule delays, cost over-runs, low productivity and issues with production that would have been avoided by an experienced workforce.

Defence does not plan acquisition projects to sustain company revenue or jobs. Defence's plans are about delivering warships economically and on time in order to sustain national security. What is clear though, is that informed and early planning of projects can deliver substantially better outcomes for everybody: more reliable on time delivery and lower costs. The problems described above are typical of industry in a rebuilding phase, and the impact of these can amount to billions of dollars for individual projects. The cost of all planned naval projects may be somewhere above $75 billion. By having a proficient and productive shipbuilding industry, overall savings to the Defence budget would amount to tens of billions of dollars.

In summary, given the military requirement, the planning of naval shipbuilding projects needs:

- to be done early and with a very long time horizon
- Defence to have an expert understanding of the shipbuilding task and the shipbuilding industry
- constant, detailed engagement with the shipbuilding industry
- to encompass all shipbuilding projects, with a clear understanding of interdependencies
- to be done with a clear vision of how we want the Australian naval shipbuilding industry to support the nation in the very long term.

Planning individual projects

What is clear from engagement with industry during the development of this plan were several practical points about individual projects:

- projects start too late to replace ships before their known end of life
- the duration of projects was too short
- time allowed between approval and delivery of the first ship was too short to allow for proper systems engineering and other upfront activities
- industry had many good ideas that could help without interfering in Defence business.

To create more practical timelines for individual projects, the capability planning process should be adjusted so military planners set the date new ships are to be available to replace older platforms and define their operational requirements, then all preceding project durations and milestones are set out by the Defence Materiel Organisation. As discussed above, the Defence Materiel Organisation needs to do that on the basis of a better understanding of the industrial task and with close and early consultation with industry. This is a small, but important change, for three reasons:

- When project plans are created with a capability viewpoint, there tends to be an optimism that confirms their achievability, qualified by statements about risk that do not portray its true impracticality. This conspiracy of optimism is evident in mega-projects—defence and civil, and all around the world. Once a statement is made about how a project can be done, ambition takes hold and it is very difficult to change plans.
- In setting out a plan, the Defence Materiel Organisation not only has people working in naval shipbuilding projects that have practical experience and daily contact with industry, they are closely connected to people managing the current fleet, so are part of a continuous conversation about the ageing and service life of ships, rising costs of sustainment and timelines to replace.
- The daily contact with industry also means that the Defence Materiel Organisation can predict workload patterns and set individual project timelines to optimise the overall scheme of projects and achieve a better result for Defence. For example, starting a project earlier than might be necessary to take advantage of an opportunity to compete a project when companies are looking for work.

Lessons learned that guide good planning include:

- Allowing ample time between final government approval and the start of hull block fabrication for a rigorous systems engineering process to be completed. Any flaws in the requirement set at this stage of complex warship development are very expensive to fix at any later stage in a project.
- This time must also allow for development and review of the shipyard build strategy, which covers manufacturing strategy, facilities, tools and processes—especially any upgrades—and the build schedule. An expert third party should review all of these.
- Ensure time for production engineering is clearly provided for, and that the size and experience levels of the available production engineering workforces are consistent with the time allowed.
- From international benchmarks, set realistic build durations for first of class and follow-on ships, allowing for both new design and first of type productivity drop off in the shipyard.
- Using typical ship types and current productivity measures and benchmarks, analyse the build effort required using methods similar to the First Marine International analysis in this report. This will ensure the build duration, available workforce size and productivity are realistic.
- Ensure time allowed for workforce build up is calculated using methods such as those described in section 9, and not simply guessed. Ensure any assumptions are realistic.

The plan will naturally encompass the timing of government decisions (first and second pass) and affect investment profiles, but longer time horizons and practical plans that avoid project delays or avoid added investment to keep older ships running is the objective. Also, the time between first and second pass needs to be set with a detailed knowledge of the engineering task. Too short, and design and project data developed is too shallow and results in a poor decision; too long, and money is wasted generating more and more data that does not add to the quality of the decision.

Integrated planning of all shipbuilding projects

When the whole set of naval shipbuilding projects is considered, other problems emerge: no opportunity for continuous productivity improvement, no opportunity to improve proficiency or grow experience levels, no viable basis for industry to make long-term investment, insecure jobs, and simultaneous competition for skilled workers.

In the 2012 Defence Capability Plan, three major projects are set to start in about the 2020 timeframe: future submarine, future frigate, and offshore combatant. Such timing aligns the peak of activity of all three projects for each stage of work: systems engineering and design, then production engineering, then production and so on. Each project would be competing for the same core of experienced people, and competing to recruit the same sort of new people to bring them up to the required capacity. They will also be retrenching skill groups in similar timeframes. The precise pattern depends on several factors, such as number of ships, but in basic terms this synchronous phasing is counter productive.

As discussed in section 2, a shipbuilding project broadly has four stages: systems engineering and design, production engineering, production, and test and activation. They all overlap, but achieve each peak of activity in that sequence.

In the scheme of all naval shipbuilding projects, the aim should be continuity of each individual element, not the nose to tail continuity of whole projects. The major design phase of each project should be timed so they run nose to tail. Similarly, production engineering should be spaced generally to allow industry to apply experts to one major project at a time. If this is not possible because of other constraints, then more time can be allowed for simultaneous activities because of limited resources.

Sequencing the timing of ship production across multiple projects is more difficult because that period of activity in each project can be substantially different. Production in some projects might only run for five years, projects like future submarine will run for closer to 25 years. What needs to be avoided is aligning the production build-up phase of multiple projects. Projects need to be allowed reasonable time to build up production capacity. Providing the front-end engineering is done properly, shipyards are able to steadily build up capacity over time by recruiting qualified tradespeople who have not worked in shipbuilding. With training, good supervision and a short, but reasonable period of time, they can quickly become productive.

By the time the first three stages are aligned across multiple projects, especially if production is of dramatically different durations, it may be impossible to align the final test and activation stage. This is where enough time for the likely available resources needs to be allowed in the schedule, by both Defence and the companies engaged.

This plan will not propose one specific view on how all the projects in the Defence Capability Plan should be sequenced. There are too many variables and choices that mean a single prescription is not sensible. During the study, different scenarios were examined (see Annex C), which revealed different benefits. Development of the optimum solution for prevailing circumstances will take further analysis in cooperation with the teams developing force structure options for the Defence White Paper.

In terms of the whole schedule of naval shipbuilding projects, as for individual projects, the action required is for the Defence Materiel Organisation to undertake planning with a clear understanding of all capability needs and the entire industrial setting, and in discussion with capability planners and industry. Discussing different needs and planning options will optimise solutions and produce a better plan. This is not a one off or short-term task, this is an ongoing role for the Defence Materiel Organisation. The plan will only remain viable if it constantly adjusts for changes in requirements, budgets, developments in industry, new technology, new practices and progress and problems with projects underway.

The Australian Government has shipbuilding projects beyond Defence, notably patrol boats for Australian Customs and a replacement by 2018 for *Aurora Australis*, Australia's Antarctic research and resupply vessel. The three agencies involved should coordinate plans to optimise outcomes for government.

Workforce retention

The expert industry panel agreed unanimously that when people leave the shipbuilding industry as it declines, they rarely return. Instead they find similarly challenging but secure employment in other sectors, and stay there. This is not new—it has been evident for many shipbuilding cycles over past decades. What it does mean is that in the past each new cycle is built upon a largely inexperienced workforce and this results in problems, particularly low productivity.

There are different ways to solve this problem. Ideally, each skill group can find continuity of their particular work, so not only retaining the people, but building their skills and experience. Clearly that is not always possible. What can be done is to allocate work that occupies the skilled workers, even if it is not in their specific domain. For example, people skilled in welding submarine pressure hulls will not advance those skills welding thin, mild steel for a support ship. But they are at least retained in the industry, which is far better than their departure and having to rebuild the skill set from zero.

Part of the overall plan for naval shipbuilding needs to consider retention of a core of skilled, experienced workers. This is discussed further in section 8. Evaluating options has to consider cost differentials. If it was more expensive to execute a project in a way that solved a broader workforce retention problem, that additional cost has to be balanced against the higher cost of starting a future project with an inexperienced workforce. The First Marine International analysis and various RAND studies point to these additional costs being substantial. In the case of Air Warfare Destroyer, the cost impact of the cold start could have been avoided if a lower cost project had been done to retain a core of skilled, experienced shipbuilders during the downturn between ANZAC, Collins and Protector projects and the start of Air Warfare Destroyer. In the case of ASC and submarines, Adelaide has had the advantage of Collins maintenance to retain skilled workers. Submarine construction skills will have faded to some degree, and some people departed, but many remain.

In service upgrades

Sometimes referred to as mid-life upgrades, major systems upgrades to ships in service are another important opportunity to retain and develop skills. For the Future Submarine Program, this will be a key factor in considering the Collins Service Life Evaluation Program. Arguably, what this Program does for submarine design and construction skills is equally important to the Future Submarine Program as it is to the Collins class. This is recognised in Defence.

There will be other warships that need major system upgrades in the future, and that needs to be an influential part of the planning for both new construction and those upgrades. As discussed in section 5, often acquisition and sustainment work is done in different cities, so will not benefit the entire workforce, but that consideration is part of the detailed planning. For example, it may mean the seemingly obvious location for the work is not chosen.

ROLLING BUILD PROGRAMS

Rolling build program is the term used in this report to describe an ongoing shipbuilding project. This is where ships are built at a steady cadence supported by an engineering program that deals with equipment obsolescence and minor system changes, and also a research and development program that develops new technology for major equipment and capability upgrades.

Unlike the start and stop nature of pre-defined build projects, these projects are set up to run for an indefinite period. Ideally, the project will be designed to build ships at a certain interval, for a certain life of type so that when the last ship is built, the first requires replacement. For example, for a fleet that requires 10 ships of a certain type, the rolling build program could build ships with a 20-year life delivered at two yearly intervals.

Just as important as the build cadence are the engineering, science and technology programs that continually support the build of current and future ships. A project without this support will fail. For example, even with a stable design, ships in construction require engineers to design and develop solutions for equipment and materials no longer in production, or where the manufacturer changes its equipment configuration. This happens all the time in shipbuilding and manufacturing in general, sometimes it is forecast and other times it comes as a complete surprise when equipment turns up in the shipyard. However it occurs, and it requires a proper engineering design process to make the change.

Operational capability

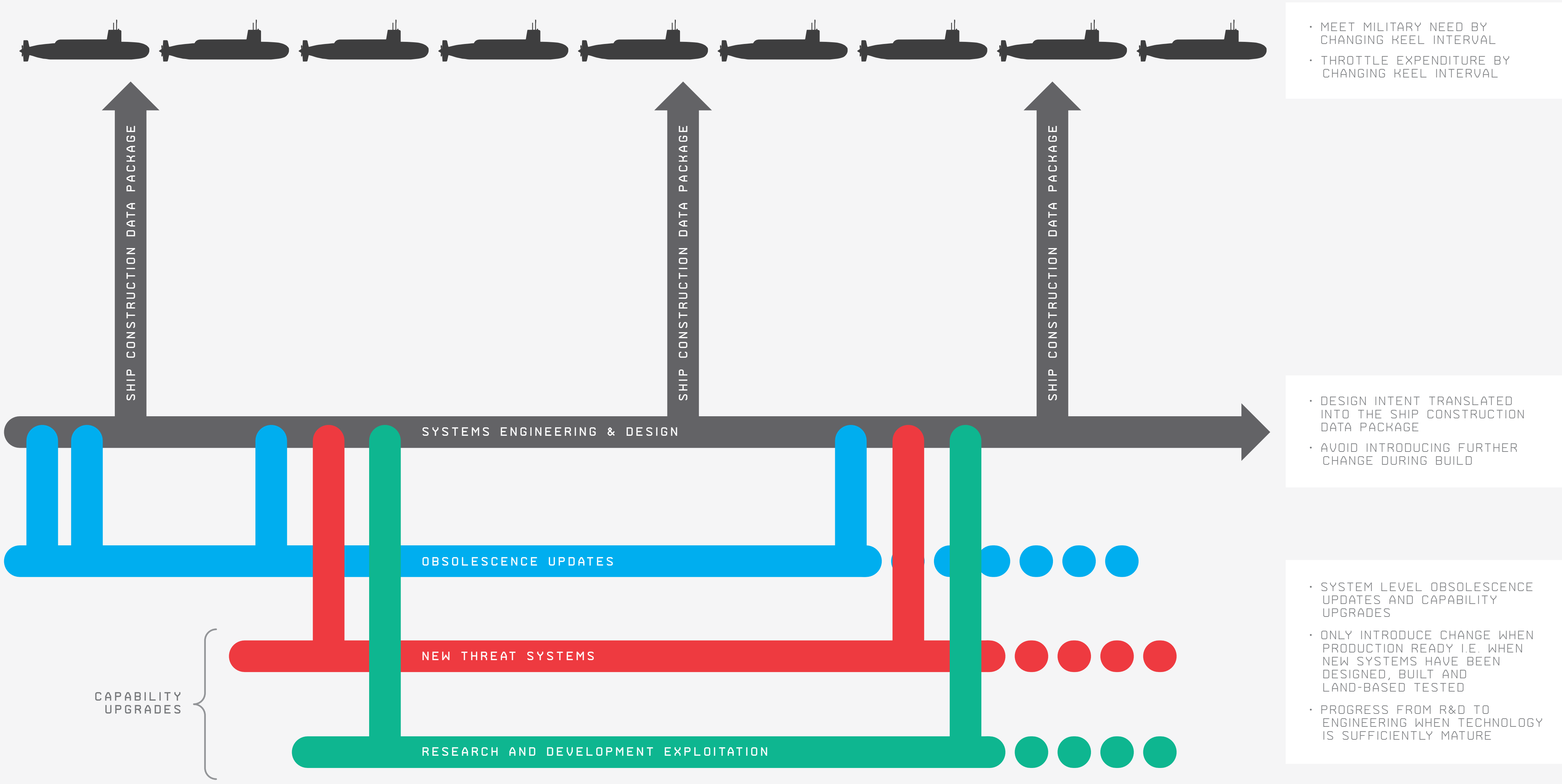
For warships, there is always a need to upgrade systems to keep them effective against evolving threats. New technology delivers new threats, and new systems are required in response. To maintain the operational effectiveness of warships, scientific research and development programs are needed to develop new technology and new systems to steadily evolve the design baseline of successive ships. They need to be a permanent, funded feature of a major naval shipbuilding project. Embedding these programs inside a major project directly connects research and development to ship production, which means costs, schedules and risks are controlled and ideas have a practical and important destination. A rolling build program allows changes to be introduced progressively into a class of warship. The US Navy DDG-51 project is a rolling build program. The first ship, the USS Arleigh Burke, was laid down in 1988 and the latest ship under construction, the USS Thomas Hudner, is the 65th ship of the class. Over that 24 years, the ship has evolved through three major upgrades, called flights or batches, with a fourth under development, and countless minor equipment changes. One of the US Navy principles is to 'design a little, build a little, test a little'. Over time, all sub-systems can be upgraded or changed, without causing a dramatic shock to the momentum of the industry team executing the projects, which occurs when projects are stopped and started.

Defence budget

When budget priorities change and the amount to be invested in shipbuilding needs to reduce, rolling build programs provide the flexibility to lower annual cash demand by extending the keel interval. Again, this avoids a shock to industrial momentum. Similarly, if budget priorities change and more funds can be allocated, the keel interval can be shortened. The effect on budget demand is substantial.

BUILDING THE SKILLS

FIGURE 10.1: ROLLING BUILD PROGRAM



As an example, consider a warship whose average price is $2 billion. If the series of ships is delivered at two yearly intervals (24 months), the average budget demand is $1 billion a year. The ships would take longer than two years to build, but that is the average rate of effort. If the keel interval is extended to 30 months, the average annual cash demand reduces by $200 million to $800 million. Reduced to 18 months, the average annual cash demand rises by $333 million to $1.3 billion. Clearly not something that can be adjusted on a daily basis, changing keel interval is useful flexibility in long-term planning that does not injure the core skills of the industry. It would reduce employment levels because slower construction means a smaller workforce is required. Controlling expenditure by governing projects over time (horizontal control) is much better than starting and stopping them (vertical control), which costs money later to rebuild industry skills and capacity.

Changing strategic requirements

This approach to controlling projects is also very important flexibility for national security. If strategic circumstances change and government decides to increase the size of the naval fleet, this can be done simply by reducing keel intervals. Obviously this is not instantaneous, but it is faster than rushing through a new project, which will inevitably face problems, premium prices and likely delays.

In-service support

Two benefits accrue for in-service support from a rolling build program. Firstly, a fleet of common warships substantially reduces the cost of integrated logistic support compared to a fleet of two or more types of warship. Only one training system (instructors, facilities, courseware, training aids, simulators etc.) is required, not two or more. Spare parts management is simplified though the quantity is obviously not halved.

The other benefit is that a rolling build program underpinned by a proper engineering, science and technology program is doing the very work required to keep the in-service fleet up to date. In short run projects, that engineering, science and technology tends not to be done for the few ships that are built. If the know-how and data is not effectively transferred from the project to support organisation, in–service support becomes a problem as described by the recent Coles Report into Collins class sustainment. In a rolling build program, that engineering, science and technology work is essential. The ship modification packages required to overcome obsolescence in build or deliver capability upgrades can basically be applied to ships in service without additional non-recurring costs.

Industrial benefits

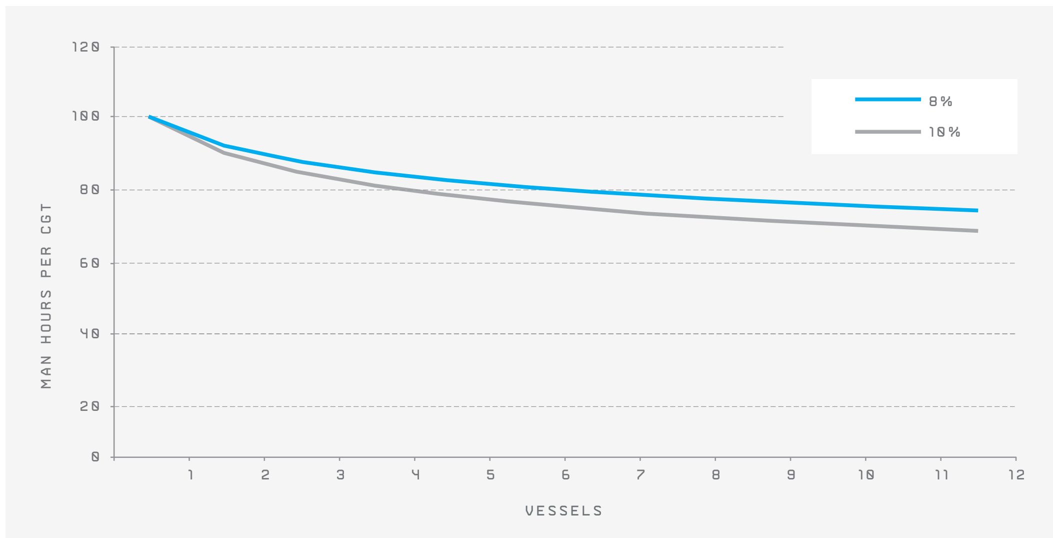
There are also important industrial benefits with a rolling build program. A steady work program allows shipbuilders to improve productivity through practice and investment, and major gains are proven to be achievable. A steady work program also allows systems companies to become more efficient though practice and investment. And it is not just basic man-hour productivity that improves, a practiced industry makes savings in almost everything it does. An experienced workforce knows the pitfalls and avoids mistakes, which are complete savings not just percentage improvements.

A rolling build program allows the retention of the core workforce while allowing for steady changes in workload in the different areas, as well as reasonable levels of staff turnover. A rolling build program also allows for investment and long-term development of highly skilled people. For example, systems architects, people who design highly complex combat systems, take about 15 years of experience and specific training to develop. There are skills in shipyard production that take similar development periods, and without the certainty of a rolling build program, these specific skills do not get developed to anywhere near the same extent.

Shipbuilding productivity improves with every ship that is built in a series. Generally referred to as the learning curve, this is a basic manufacturing principle. The same efficiency gain is not made between every ship in a series, typically the same percentage reduction is achieved as output doubles. So the gain from hull one to two in a series is about the same as the gain made from hull two to four, then four to eight, and so on. In warship construction, learning curves of eight to 10 per cent are typical, but it can be higher for inexperienced shipyards and there are other first of class effects that lower productivity for the first ship in a series. The following graph shows an eight and 10 per cent learning curve.

For the future submarine program, just on learning curve effect alone, the effort to build the 12th submarine should be at least 25 per cent less than for the first. Note that First Marine International assesses that the first of class productivity drop off for the first submarine in a series can be as high as 95 per cent (see section 6). Add to this the substantial non-recurring engineering and start-up costs, which can equal the cost of one to two ships, the savings from one long project versus two or more short projects are considerable.

FIGURE 10.2: LEARNING CURVES



Future submarines

You do not need 50 ships in a class to have a rolling build program; the logic can apply to smaller fleets. The future submarine program of 12 boats is clearly a candidate for such an approach, and there has been much discussion about flights or batches of these submarines. When the details are settled and construction approved, it will be important for the project to develop the design of the submarine over the long term and for there to be a vision to evolve industry capability to meet the challenge of the next generation of submarines.

In basic terms, the project might be designed to deliver submarines at a steady keel interval of two years with a design life of about 25 years, noting each submarine will take about five to six years to build. There should be a longer delivery interval between the first and second boats to deal with first of class issues. There does not need to be a longer interval between batches because the engineering, science and technology programs that would deliver new designs can work in parallel to the build project so that all designs, equipment and production data is ready for the first ship in a batch without disrupting the momentum of the build project.

Surface combatants

Major surface combatants are another class of warship suited to a rolling build program. They are required in similar numbers to future submarines and are similarly complex. Known as destroyers and frigates, there is little in the modern use of these terms to distinguish the ships. The Royal Australian Navy typically operates a fleet of 12 to 14 surface combatants, with the fleet today comprising eight ANZAC and four FFG-7 frigates.

The current destroyer project is scheduled to deliver its last ship in 2019. Initiated by the 2009 Defence White Paper, the future frigate project is scheduled to commence in about 2021 with first ship delivery in about 2026. Merging these two projects in to one rolling build program is an opportunity worth close examination.

A rolling build program for major surface combatants does not mean all ships are the same. The essence of these programs is that, underpinned by engineering, science and technology, they can progressively evolve design to meet different operational requirements. Every proposed change needs to be examined and shown to be achievable, but it seems practical that the Air Warfare Destroyer could evolve to meet the needs of the future frigate. Using the US Navy principle of 'design a little, build a little, test a little', the evolved ship might in the longer term be quite different in configuration to the current ships.

Smaller ships and projects

Rolling build programs are not suited to all projects. There is no hard and fast rule, but the key variables are the number of ships required, complexity of systems, design life and the pace of technology upgrade required to maintain their relative fighting capability.

While modern patrol boats incorporate some complex systems like larger warships, their smaller size means their construction period is shorter and shipyards tend to build them with shorter keel intervals. For example, for the Cape class project, Austal in Western Australia is building eight ships each with a construction duration of two years, all delivered in three years, with a design life of 20 years. This means that the construction project will take six years overall, with an interval of 14 years before the first replacement has to be delivered. For a similar navy patrol boat project, this could be adjusted to a keel interval of two years so that by the time the last ship is delivered the first replacement is required. Whether this is an economical approach depends on precise circumstances, but it would at first appear not as viable as one short production run. However, if there was the demand for more ships in the class, or to constantly upgrade the systems onboard the ships, it might well be cheaper to extend the keel interval and steadily introduce change as each ship is built.

For a more complex ship like the Offshore Combatant Vessel that has different systems fitted in a common hull, a rolling build program could well be the right approach for 20 ships for several reasons. Capability planners might want to reprioritise delivery of the different mission ships, so exactly which model is required can be changed before the detailed build configuration is finalised for each. Rapidly changing technologies and systems can be incorporated as they become available.

One of the arguments against a rolling build program for small, simpler ships is the constant overhead burden. This has to be challenged. Not only can we expect better and improving productivity in shipyard production, we can expect and should demand the same for design and production support organisations.

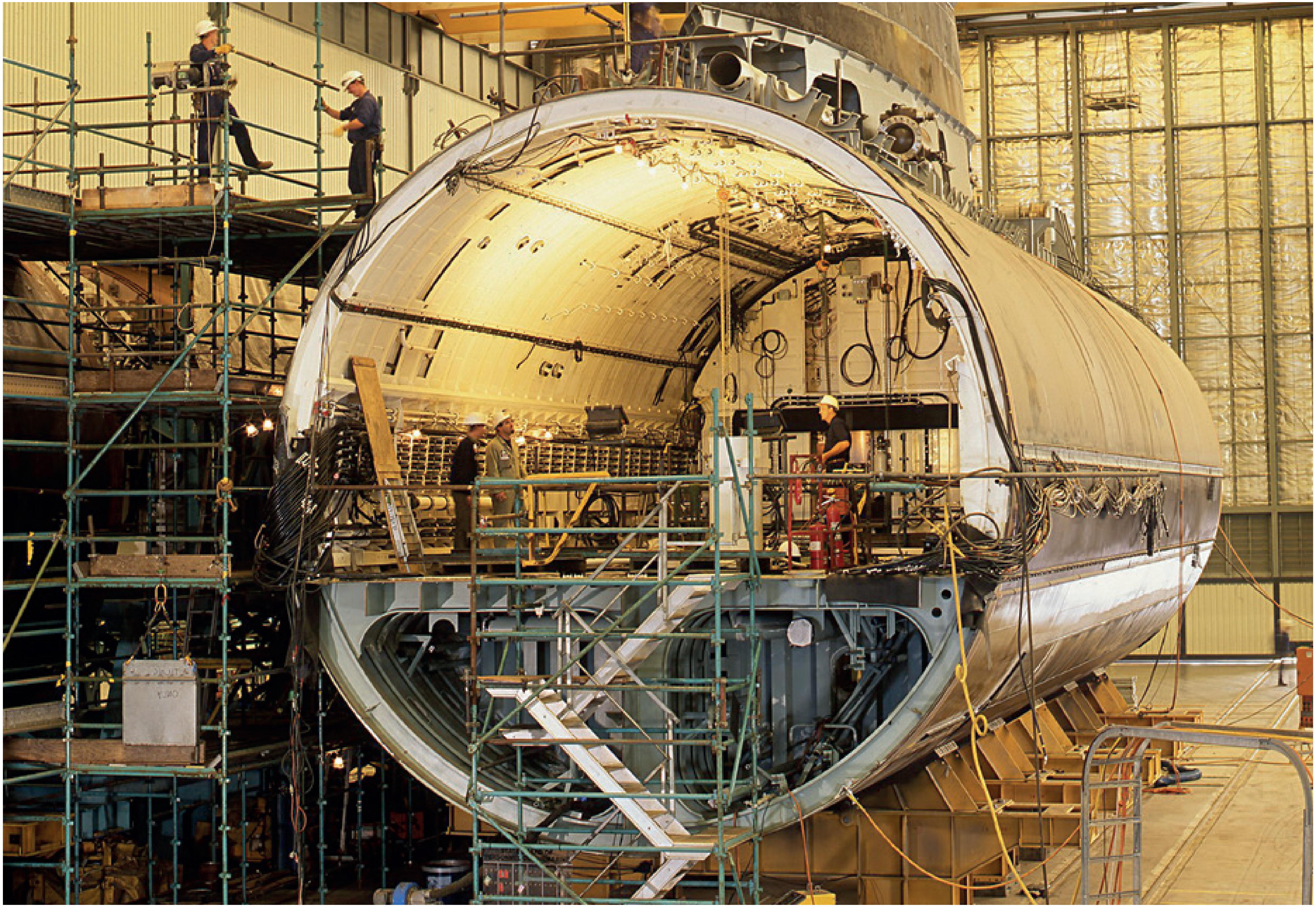
One of the observations of the expert industry panel was that technology and systems are probably not mature enough to make a common platform viable today for the Offshore Combatant Vessel. One concern is the off-board mine hunting systems needed to work with a platform not specifically designed for mine hunting are not yet proven or in production.

DEFENCE MANAGEMENT STRUCTURE

The last point in the terms of reference for this work sought a proposal for arrangements within Defence, particularly the Defence Materiel Organisation, for ongoing management of the naval shipbuilding program. The change proposed is small as most of the capability planning and acquisition process is in place.

Described above is an adjustment so that the Defence Materiel Organisation leads the initial formulation of project scheduling for all naval shipbuilding projects, given the operational requirements and need date from capability planning. The second adjustment is internal to the organisation and involves placing the management of all naval shipbuilding projects in one group rather than across divisions, that is, developing a "start up team". That group needs to be centred on the people managing current projects, so the realities of project execution and current knowledge of the shipbuilding industry truly influence the planning decisions.

In addition to an ongoing management structure, consideration will have to be given to the people and other resources needed to fulfil any Government direction to implement this plan. Complacency and any assumption improvements will just happen must be avoided. Given the importance of not losing skilled, experienced people, early attention will need to be paid to the workforce reductions that have already started.



11

A FUTURE FOR AUSTRALIAN NAVAL SHIPBUILDING

A FUTURE FOR AUSTRALIAN NAVAL SHIPBUILDING

THERE IS A FUTURE FOR NAVAL SHIPBUILDING IN AUSTRALIA FOR TWO REASONS: PRIMARILY FOR NATIONAL SECURITY, BUT ALSO FOR ITS WORTH TO THE NATION MORE BROADLY.

Planning for a national shipbuilding capability assumes Australia will still need warships in 50 or 100 years' time, whether they be submarines, destroyers, frigates, patrol boats, minehunters, hydrographic, amphibious or support ships. This report works on that assumption. Discussion on the importance and nature of military capability is, as stated previously, a matter for Defence White Papers and other national security assessments.

A high performing naval shipbuilding capability is a national effort, involving many companies, education and training institutions and government agencies. That national capability is about skilled people employing a wide range of proven tools, processes and facilities to design and build warships. The people have to be skilled in systems engineering, ship design, production engineering, ship construction and mega-project management to deliver safe, quality and efficient shipbuilding projects. Optimum performance is not achieved in one project, or even in one generation of projects. To become a truly proficient shipbuilding nation requires a clear vision, and a plan that spans a number of decades.

The Spanish Armada and the shipbuilding company Navantia have been involved in a similar effort to build a national shipbuilding capability. The Defence Materiel Organisation would like to acknowledge the help and encouragement that they have provided during the development of the Future Submarine Industry Skills Plan. Cooperation in the future with projects like the Spanish F-110 or United Kingdom Type 26 frigate depends upon clear long term plans that enable early, practical planning on shared research, development and engineering efforts.

Australia has proven it is capable of designing and building warships. Performance on the most recently completed projects: ANZAC ship, Collins submarine and Armidale patrol boats, is generally good. The projects each had their problems, no project is ever perfect, but given experience, Australians have shown the ability to handle the challenges and keep learning and improving.

The aim of a long-term plan for naval shipbuilding in Australia is to enable Australia to acquire warships as required, safely, with cost and schedule at least as good and reliable as any other world source. To achieve optimum levels of shipbuilding performance means having very experienced people leading teams of skilled people with varying levels of experience, taking on graded challenges in designing and engineering warships. Experienced production managers and workshop supervisors lead teams of skilled workers who work in profitable shipyards with impeccable safety records, well proven processes and machinery, and high, ever increasing levels of productivity.

With a long-term and ongoing shipbuilding plan, experience and time, this can be achieved.

SHIPBUILDING AND NATIONAL SECURITY

The 'technology edge' is becoming more and more important in military capability. Security controls are tightening on the sale of advanced military technology and Australia will be able to buy warships from very few countries in the future if it wants the advantage of the latest technology. As a principle of sovereignty, Australia should possess an industry able to design and build the destroyers and submarines central to its maritime defence.

Expert industry panel input into this study makes it clear that industry believes Australia will need a real shipbuilding capability in the future. This is not self-serving; their rationale is national security and the changing global shipbuilding environment, not company business.

SHIPBUILDING AND THE NATION

Naval shipbuilding is at the core of this country's advanced manufacturing industry. Submarines and destroyers are amongst the most complex and largest machines manufactured in Australia. Building them develops a wide range of manufacturing skills and drives innovation, both in technology as well as manufacturing practice.

With continued contraction of activity in the Australian manufacturing sector and a changing national economy, there has been extensive debate about the future of the industry. In August 2011, the Prime Minister commissioned a 'high-level taskforce [to] map out a shared vision for the future of Australia's manufacturing sector and help strengthen local firms as they adapt to changes in our economy, including the rise of Asia.'

Released in August 2012, the final report of the non-government members of the taskforce concluded 'manufacturing is an important and dynamic part of the Australian economy with deeply embedded and mutually reinforcing links with primary production, utilities, construction industries and the services sector. Manufacturing can and should continue to play a key role in the development of the Australian economy and its ongoing strength, diversity and resilience.' Further, 'manufacturing makes large direct and indirect contributions to national output, employment, investment and innovation. It makes disproportionally large contributions to exports and research and development'. These themes were echoed in the Australian Government's recent Industry and Innovation Statement: "a vibrant manufacturing sector is essential to a dynamic and diverse Australian economy".

Naval shipbuilding cannot be justified simply because it is manufacturing. Shipbuilding can be a part of Australia's manufacturing industry, but not as an endlessly subsidised component of this industrial base. Today, when the price of ships built overseas is compared to local prices, there is argument that local build premiums are too high and economically not justifiable. The problem with this is that Australian naval shipbuilding is, once again, largely inexperienced, and prices quoted are burdened by the cost of re-building shipbuilding skills and capacity. Also, as discussed previously, overseas prices are not always consistent and some contain subsidies.

To make a reasoned judgement on the value of naval shipbuilding in Australia requires industry to be given the opportunity to achieve world-class performance. In 2010, the Air Warfare Destroyer project commenced manufacturing hull blocks in three shipyards: one shipyard was brand new, the other two established but inactive in shipbuilding. Skill and experience levels were patchy. Three years later, productivity is low, but the level of skill, experience and manufacturing technology that has been grown is very respectable. All indications are that this learning is not slowing and with more experience, the capability could be impressive. The evidence is Australia has been very good at shipbuilding in the past, has quickly rebuilt some of that capability today, and can learn quickly.

While the industry redevelops shipbuilding skills, prices will be higher because of the investment required for recruiting, training, facilities and productivity improvement. Given the chance, Australian naval shipbuilding can be world-class.

A FUTURE FOR AUSTRALIAN NAVAL SHIPBUILDING

MANUFACTURING INTO THE FUTURE, PROFESSOR GÖRAN ROOS

Manufacturing, or the business of making things, is a critical component of any advanced economy. Manufacturing globally is:

- the biggest spender on applied research and innovation, with flow-on effects for the rest of the economy
- a key driver of productivity improvement
- responsible for the biggest share of world trade and critical for export earnings
- the largest driver of high-value services
- the largest generator of employment, with between two and five jobs created in the rest of the economy for each job in manufacturing.

2011, *Manufacturing into the future*, Professor Göran Roos.

A SUCCESSFUL VISION MADE REAL

To illustrate that it can be done in Australia, the Air Warfare Destroyer and Landing Helicopter Dock projects have provided a good insight to the shipbuilding vision of Spain. In the period before the 1980s, Spain was in a similar position to Australia; navy ships were generally imported with local construction of some ships using imported, off-the-shelf designs. Then the Spanish Navy and industry worked together to create a long-term plan for indigenous naval shipbuilding.

The plan has been successful. Spain has designed and built patrol boats, frigates and amphibious ships. It has designed a submarine and the first boat is now in production. The country is now the third largest exporter of warships in world rankings. Naturally these projects have had their challenges, but the clarity of and commitment to the long-term vision held means Spain is now regarded as a genuine naval shipbuilding nation.

The diagram on page 142 illustrates its plan.

Key points to note are that the plan is long-term. It takes a graduated approach to building up the different skill groups involved in shipbuilding, and it works progressively from simple to complex warships.

Conceived in the late 1980s when the Spanish were dissatisfied with a project aiming to deliver a common European frigate, the plan recognises that the stages of growth for indigenous naval shipbuilding are:

- fully imported warships
- imported off-the-shelf designs and local build, which builds up indigenous production skills
- progresses to co–design, working with an established foreign designer to build up indigenous warship design skills (separately covers both platform and combat systems)
- consolidates the industrial base with locally designed and built warships, and then
- moves in to the export market for designs or complete warships.

As this experience shows, each step needs to be taken and consolidated, and it would be foolish to try and skip levels.

For Australia it is also particularly important to note the cost structure of each level. When there is no naval shipbuilding industrial base, imported ships are cheaper than the nation's first efforts to build their own, which causes the hesitation all nations experience in taking this step. Co-designing a new warship is also structurally more expensive than buying an off-the-shelf design, which causes another hesitation. But having established an indigenous design and production capability, ships should cost no more than from foreign suppliers, and will probably be cheaper because interface layers are removed. When export sales are achieved, overhead costs are amortised and ship prices reduce to what should be their lowest cost structure. The global price for a warship depends upon factors external to each project, including currency exchange rates, national labour costs, shipyard throughput and subsidies. All these global factors are changing, and there is no guarantee they will favour importing warships for much longer.

The Spanish plan also shows a sensible progression within each layer. Start with the simpler challenges—patrol boats and supply ships—before progressing to the more complex amphibious ships and frigates, and take on the most complex challenge of a submarine last of all.

PLANNING THE FUTURE FOR AUSTRALIAN NAVAL SHIPBUILDING

A long-term visionary plan for a national naval shipbuilding industry can succeed. The hallmark of a good plan is to steadily and continually build up experience and capability over several decades and projects. Take only one step up in industrial capability with each project, and start with the simpler warships and move progressively to the most complex—submarines. What the Spanish effort also shows is that it requires commitment and perseverance to push through the more expensive layers to achieve a competitive industry that can economically deliver its own nation's warships .

Developing this for Australia will require detailed planning, and it will need to be flexible and adjust as circumstances evolve. The plan will need to embody the principles outlined above. Current projects need to build up ship production capability and experience. The next generation of projects have to consolidate that expertise, and build the next level.

In the following generation, select projects will focus on co-designing carefully chosen elements of a warship. Different projects will take on different elements, one might be used to develop small hull form and structure design skills, another might focus on elements of the combat system, while another might develop an indigenous integrated platform management system.

In the generation of projects after that, all those skills come together to undertake the design of a complete warship, starting with something like the offshore combatant vessel, then the next destroyer, then the next submarine.

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A FUTURE FOR AUSTRALIAN NAVAL SHIPBUILDING

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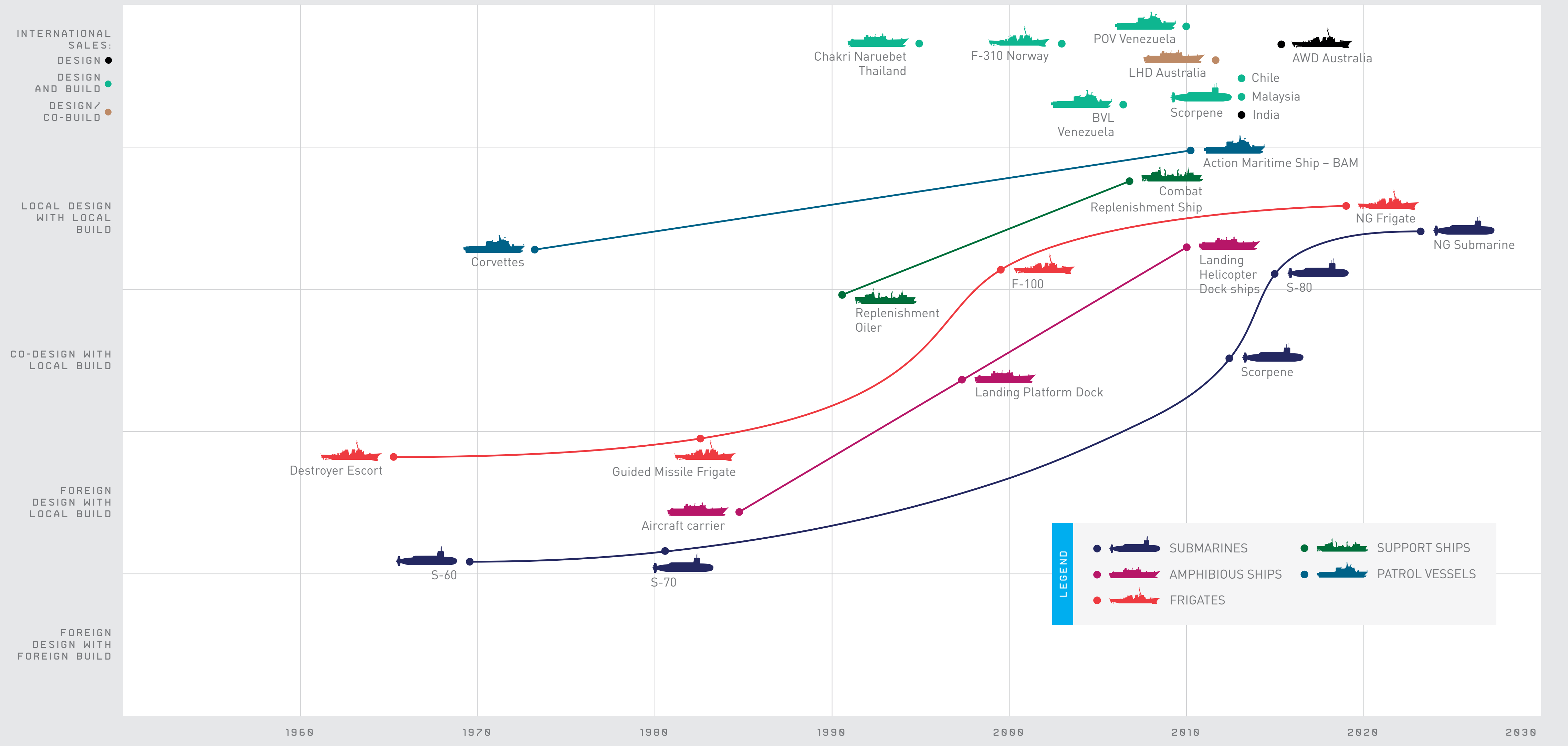
FIGURE 11.1: SPANISH EVOLUTION



While much of that design will involve existing technology, work should also be done to research and develop selected technologies. With a plan developed in close consultation with both industry and the Defence Science and Technology Organisation, this science and technology work should be an integral part of each shipbuilding program so the practical objective of ship installation remains clear.

If surface combatants (the destroyers and frigates) become a rolling build program, part of the underpinning science and technology program should look at the feasibility for developing an Australian warship combat system. This feasibility study would need to examine architecture, future operational requirements, future technology, costs, benefits and all risks and opportunities. Any implementation would need to be in small, measured steps. Such a system should be scalable so that functional elements of it can be used in patrol boats and support ships, as well as high-end surface combatants and submarines.

Developing architectures for combat and platform systems is important underpinning to discussions regarding cooperation with other nations' projects such as the United Kingdom's Type 26 or Spanish F-110 frigate. The architecture enables detailed, practical agreement about shared investment in technology research or specific sub¬system development such as the Integrated Platform Management System.

SUMMARY

A naval shipbuilding industrial base in Australia will be important our future national security, and benefit the nation more broadly. A competitive Australian naval shipbuilding industry will depend upon people skilled in systems engineering, ship design, production engineering, ship construction and mega-project management. Australia can achieve world-class levels of performance; however, this optimum outcome will take vision, perseverance, planning and time.

12

CONCLUSION

CONCLUSION

FROM THE EARLY 1980S, AUSTRALIA BUILT A VERY CREDIBLE NAVAL SHIPBUILDING ABILITY THROUGH THE COLLINS SUBMARINE AND ANZAC SHIP PROJECTS, BUILDING A TOTAL OF 16 WARSHIPS FOR THE AUSTRALIAN AND NEW ZEALAND NAVIES. MINEHUNTERS AND PATROL BOATS WERE ALSO BUILT. A WORKFORCE OF MANY THOUSANDS WAS BUILT UP IN THE VARIOUS SHIPYARDS AND SYSTEMS COMPANIES.

Numbers declined to a very low level as the projects finished in late 1990s and early 2000s, before rising again with the commencement of the current era of naval shipbuilding with the Air Warfare Destroyers, Landing Helicopter Dock warships and patrol boats for Australian Customs. Today, there are around 4,000 Australians involved in naval shipbuilding in Australia. Much of this workforce was generated in the last five years.

Submarines are very complex machines, with many unique design features. A submarine project is the most difficult of all shipbuilding projects. A general principle offered by one very experienced shipbuilder was that every element of a submarine project takes more time and effort to complete than for all other warship projects (leaving aside basic scaling factors such as size and number built).

Work in support of this study and earlier efforts by RAND and other organisations show that Australia does possess a core of skilled and experienced warship designers. Australia has a good record in designing patrol boats and support ships, and it was the design by WA company Austal that was chosen against international competition for the *Independence* variant of the US Navy Littoral Combat Ship. Submarines are the most complex warship to design and while Australia has that core of skilled people able to contribute to the design of a new submarine platform we will need to partner with a proven submarine design organisation. That organisation will contribute people to the design team and provide a proven framework of tools and processes.

Work in support of this study also shows that Australia has a strong cadre of people who can build complex systems and construct warships. Australia has good skills in the development and integration of combat and platform management systems. Australia has also developed world–leading sub–systems in areas such as electronic warfare and sonar. These skills have been built up over several decades, benefitting from the continuity of work and challenge of successive projects.

Shipyards have the facilities to build the warships required, although some investment would be required to develop launch points for the larger supply vessels. A weakness with ship production today is low productivity, which is due to the industry being built up following the decline in shipbuilding in the 2000s. The consequence of allowing skills to decline to very low levels has been shown in current projects to cost time and money. There is truth in the maxim that the most expensive thing you can do in shipbuilding is stop.

To meet the challenge of the future submarine and other naval projects, shipyard workforces will need to evolve to achieve the right balance of skill groups, strengthen skills and most importantly acquire experience. Shipyard organisations will need to refine their engineering, planning and production processes and innovate to improve productivity. Productivity is something that can be relatively easily improved with good leadership and practice. For Australia's shipyards, there is no fundamental impediment to achieving world–class performance.

Given the scale and complexity of the future submarine project, all practical actions should be taken to retain and develop the skills that project will need. The project will always be a challenge, but any stumble at the start would have very expensive consequences.

Today, Australia has some options to purchase submarines and complex warships from overseas. As the global market retracts and technology release becomes more restrictive, these options will reduce. There is a good argument to be made that Australia may not be in a position to buy conventional submarines or their design from overseas for the generation of submarines that will in 20 to 30 years replace the future submarine. Furthermore, the design of a submarine is highly sensitive national security information.

Australia should use the next generation of naval projects, future submarine included, to establish a genuine national capability to design and build complex warships. Government, Defence and industry would need to develop an itemised view on what naval shipbuilding capability needs to be developed in Australia. Complex warships like submarines and surface combatants need to be at the centre of that plan. This does not necessarily include support ships because they are built to commercial shipping standards, where there are more global suppliers and no classified technology issues.

Our national security strategy needs a detailed, practical naval shipbuilding industry strategy. This will not be a large, expensive industry. In a national manufacturing industry of about one million people, this will be a small, proficient and innovative industry.

CONDUCT OF THE STUDY

Firstly, thank you to all the people who contributed to the expert industry panel that supported this study. In particular, thank you to Mr David Mortimer AO who chaired the panel. Many organisations participated and virtually without exception it was the chief executive who attended. This is a clear reflection on the importance of the Future Submarine Industry Skills Plan.

The panel was a vital element of this study. It allowed the principal companies and other organisations involved to talk about naval shipbuilding projects, lessons learned, problems, risks and opportunities that affect Defence and industry today, and those that lie ahead. Discussions by the panel can be characterised by their practicality and strategic nature; they certainly were not about the interest of individual companies or industry profitability. Discussions centred around how Defence and industry could work together to understand the whole scheme of shipbuilding and be able to optimise the outcome for Defence: warships at lower costs, delivered on time and with the requisite capability. Industry and its workforce can also benefit from a more integrated and optimised long term plan.

The study was also well supported by First Marine International. Damien Bloor and the team from its UK and USA operations did good work on benchmarking the capability and capacity of the principal naval shipyards and analysis of the potential of this industry in Australia.

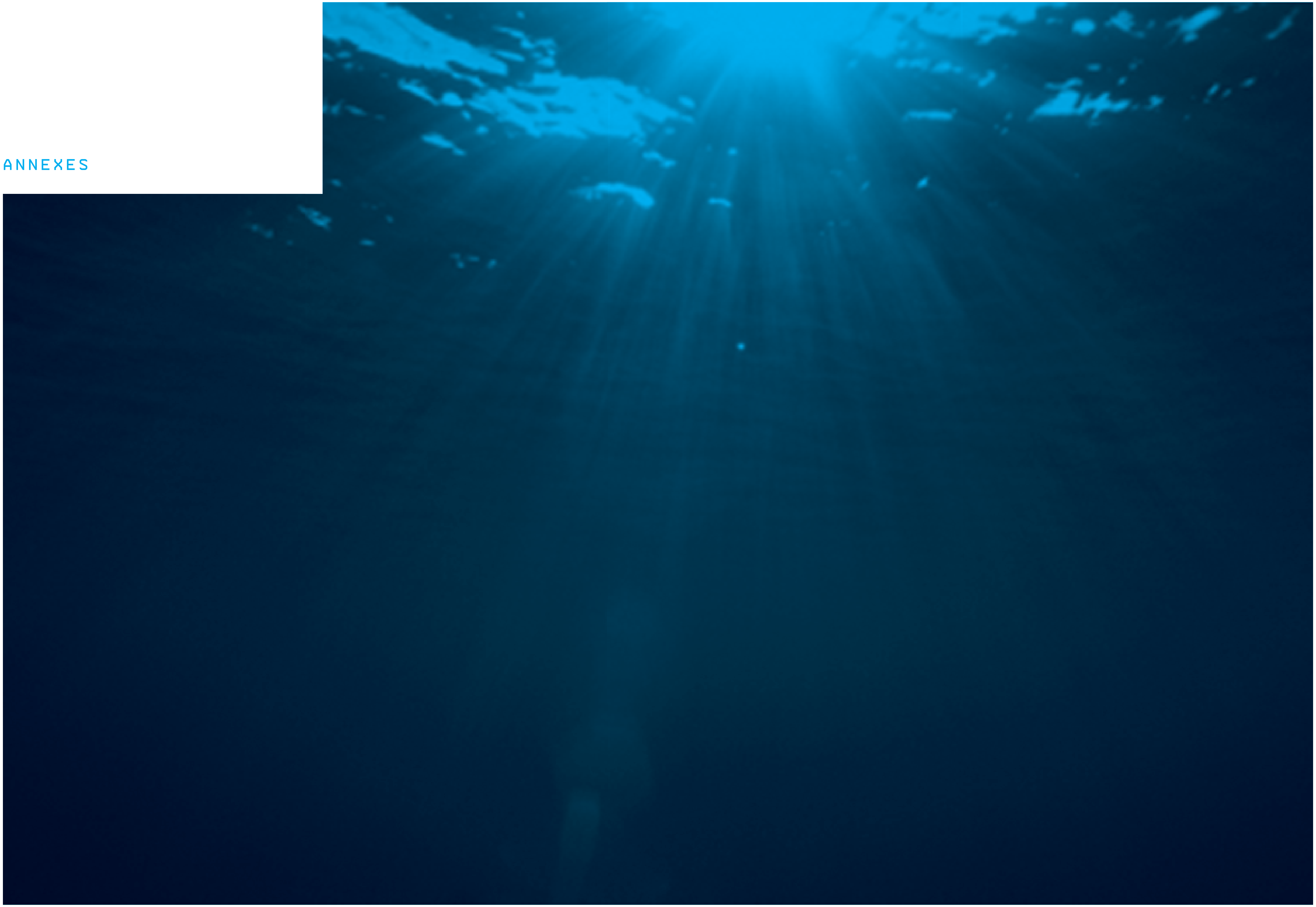
RECOMMENDATIONS

The following set of recommendations draw upon all sections of this report. They are deliberately written as principles rather than a long list of specific tasks.

To build the skills to build the future submarines and the other warships required for the future fleet, the following actions are recommended.

1. Without adversely impacting the Australian Defence Force's capability, planning of the whole scheme of naval shipbuilding programs should be optimised to provide industry more predictable, better sequenced and long term work: the necessary foundations for innovation, business investment, productivity and performance improvement. This of course does not mean that all naval projects in the Defence Capability Plan will necessarily be built in Australia. Rather it means that naval shipbuilding projects should be planned with the aim of retaining wherever practical the current Australian workforce to place Defence and industry in the best position possible at the start of the next generation of projects. Defence and Government should take early action to ensure current workforce reductions are not causing the loss of skills important to future projects.
2. Defence should consolidate planning for all new warship programs into one group centred around the people managing today's projects so that genuine and current experience is applied. The initial schedule planning of naval projects for first entry into the Defence Capability Plan should be done by the Defence Materiel Organisation based on warship need dates and capability requirements provided by Chief of Capability Development Group and Chief of Navy.
3. The Defence Materiel Organisation should engage in more detailed discussion on a frequent and ongoing basis with organisations involved in naval shipbuilding, companies, unions and industry groups. No plan should be approved that is not broadly seen as being practical in terms of industry capability and capacity, schedule and budget.
4. Defence sponsorship of individual skills development schemes such as Skilling Australia's Defence Industry has been worthwhile for people involved in naval shipbuilding, particularly apprentices, and should continue. The Defence Materiel Organisation should develop and maintain a nationwide skills matrix based on matrices already used in the shipyards, extending to systems development, and use this to guide skills development sponsorship. Options to second select people to organisations with active submarine design and build programs should be investigated.
5. Industry should develop a clear plan to improve shipbuilding productivity in Australia, including setting specific targets, and commit to Defence and Government to delivering these dividends. Defence should continue to benchmark productivity on an annual basis.
6. Defence should structure the Future Submarine Program as a rolling build program, including establishing structured, funded and ongoing engineering and science and technology programs to deal progressively with equipment obsolescence and capability changes.
7. Defence should pursue the opportunity at the completion of the three ship Air Warfare Destroyer Program to flow key skills and expertise into the Future Frigate Program.
8. Working with industry and the Defence Science and Technology Organisation, the Defence Materiel Organisation should, as part of these programs, research the practicality and worth of a common architecture for Australian warship combat and platform management systems. This architecture would guide investment in technologies and products over the longer term.
9. Defence should re-examine the Offshore Combatant Vessel program to determine if technology and system readiness levels are sufficient for new types of equipment likely to be required to make the common platform solution technically viable and economical. Technical risk and other reasons might point to a better solution being to separate the patrol boat requirements from other requirements and consider two separate projects.
10. The Department of Defence, through the Defence Materiel Organisation, should work with the Australian Customs and Border Protection Service and the Australian Antarctica Division of the Department of Sustainability, Environment, Water, Population and Communities to coordinate and optimise Australian Government shipbuilding programs.
11. Reflecting its worth in the development of this Plan, the Expert Industry Panel should be a part of the implementation process. As a guide, the panel might meet every three months for the first year and six monthly thereafter to provide views and feedback on the development of naval shipbuilding plans and preparations for the future submarine program.

ANNEXES



ANNEX A

TERMS OF REFERENCE

STUDY INTO THE DEVELOPMENT OF SKILLS REQUIRED FOR AUSTRALIA'S FUTURE SUBMARINE PROGRAM

TERMS OF REFERENCE

1 AUTHORISATION

1.1 The Minister for Defence and Minister for Defence Materiel have commissioned this study to develop a plan that will produce the skills across Defence and Australian industry required to successfully deliver the Future Submarine Project.

2 PURPOSE

2.1 The purpose of these Terms of Reference is to specify the scope of the study into the development of skills to successfully deliver the Future Submarine Project.

3 CONTEXT

3.1 The Future Submarine Project is a major national undertaking and is of a scale, complexity and duration never before experienced in Australia. About 2,000 workers will be directly employed in the construction of the submarines, while two or three thousand more will be working in the industry supply chain to support the project.

3.2 The skills needed will include systems design, naval architecture, propulsion and combat system engineering, production engineering, project planning and control, production scheduling, material procurement, risk management, budget control, financial accounting, contract management, systems integration, and trade skills such as welder, boilermaker, and electrician.

3.3 These skills will be generated from experience in designing and constructing other warships for the Navy, as well as from the various education and training programs available to people in Defence and industry, including trade apprenticeships.

4 OBJECTIVES

4.1 The purpose of the study will be to design a unified plan for naval shipbuilding projects, education and training programs and other actions that will sustain and grow the competence and proficiency of the Australian shipbuilding industry so that it can successfully deliver the Future Submarine Project.

4.2 The broad objectives for this study are to:

4.2.1 determine the type of skills required to successfully deliver the Future Submarine Project;

4.2.2 determine the size and profile of the workforce required to successfully deliver the Future Submarine Project;

4.2.3 determine the current capacity and capability of the Australian shipbuilding industry, in terms of skills and workforce;

4.2.4 determine the current productivity of the Australian shipbuilding industry and establish comparable international benchmarks;

4.2.5 analyse the naval shipbuilding projects currently in the Defence Capability Plan and calculate the effect these projects will have on growth of the capacity and capability of the Australian shipbuilding industry;

4.2.6 analyse current education and training programs, including apprenticeships, and calculate the effect these programs will have on growth of the capacity and capability of the Australian shipbuilding industry;

4.2.7 propose alternate scenarios for sequencing Defence projects that will better deliver the capacity and capability required to successfully deliver the Future Submarine Project;

4.2.8 propose improvements to the education and training programs that will better deliver the capacity and capability required;

4.2.9 propose other actions required to deliver the capacity and capability, including industry productivity, required to successfully deliver the Future Submarine Project; and

4.2.10 propose a management arrangement within Defence, particularly the DMO, for the ongoing management of a sustainable naval shipbuilding program.

5 METHOD OF CONDUCT

5.1 The review will be managed by the CEO DMO and the review team led by General Manager Programs, DMO.

5.2 There will be an Expert Industry Panel Chaired by David Mortimer AO and comprise representatives of the DMO, Navy, DIISRTE, Skills Australia, unions, the CEOs of the four principal Australian naval shipbuilding companies; ASC, Austal, BAE Systems and Forgacs Engineering and the CEOs of the principal naval systems integration companies: Lockheed Martin, Raytheon, Boeing, Thales, Saab Systems and BAE Systems.

5.3 The review will naturally consult widely, capturing input from all levels of the Australian shipbuilding industry including the manufacturing sector as well as platform and combat system designers. The review will engage with industry associations, unions, companies currently involved in shipbuilding as well as those that may wish to become involved in the shipbuilding industry.

5.4 The review will examine shipbuilding projects now underway and those described in the Defence Capability Plan (DCP). The naval shipbuilding projects in the DCP encompass landing craft, supply and support ships, offshore combatant vessels and frigates, along with the future submarines. Other future shipbuilding activity in Australia might include a major modification of existing ships and submarines to extend their service life. The naval shipbuilding program should be configured to grow industry's capability and capacity so that it can proficiently deliver the largest and most complex of all the upcoming projects, the Future Submarine Project.

5.5 The review will assess the need for skilled workers for the Future Submarine Project. Discussions will be held with various tertiary institutions on the development of courses to develop skills specific to shipbuilding. The review will also discuss with companies and vocational institutions the role of apprenticeships, temporary visas or skilled migration in boosting the number of skilled workers. An assessment will also be made of skills funding programs offered by Federal and State governments.

5.6 The review team will also involve companies with expertise in specific aspects of shipbuilding, such as productivity benchmarking, to assist in its analysis.

6 TIMING

6.1 The review will commence in May 2012, with work to establish the detailed scope of the tasking. Consultation with the interested parties, that is tertiary institutions, state governments and industry groups, will take place in June and July.

6.2 The review will present a report for Government consideration by the end of the year.

ANNEX B

AUSTRALIAN INDUSTRY CONTRIBUTIONS

EXPERT INDUSTRY PANEL MEMBERS

David Mortimer AO	Chairman, Future Submarine Industry Skills Plan Expert Industry Panel Chairman, Crescent Capital Partners
David Allott	Managing Director and Chief Executive Officer Australia BAE Systems Australia
John Allcock	General Manager Integrated Solutions, Raytheon Australia
Deborah Anton	General Manager, Competitive Industries Branch, Department of Industry, Innovation, Science, Research and Tertiary Education
Paul Bastian	National Secretary, Australian Manufacturing Workers Union
Andrew Bellamy	Chief Executive Officer, Austal
Garry Ferris	New South Wales Government Department of Trade and Investment, Regional Infrastructure and Services
Andrew Fletcher	Chief Executive Officer, Defence SA
Raydon Gates	Chief Executive, Lockheed Martin Australia
Kim Gillis	Vice President and Managing Director, Boeing Defence Australia
Peter Haddad	Defence Industry Unit, Victorian Government Department of Business and Innovation
Andrew Jackman	Director Maritime, Defence SA
Chris Jenkins	Chief Executive, Thales Australia
Chris Lloyd	Vice President, Maritime and Aerospace, Thales Australia
Tony Lobb	General Manager, Forgacs
Steve Ludlam	Managing Director and Chief Executive Officer, ASC
Jack Mahoney	General Manager Maritime and C4SR/Ground Based Radar Programs, Lockheed Martin Australia
Gonzalo Mateo-Guerrero	Director, Navantia Australia
John O'Callaghan	Australian Industry Group Defence Unit
Richard Price	Vice President and Managing Director, Saab Systems
Graham Priestnall	National President, Australian Industry and Defence Network
Bill Saltzer	Director of Maritime, BAE Systems Australia
Malcolm St Hill	Business Development Manager, Hunter Industry, Innovation and Investment
Davyd Thomas	Vice President Defence, Austal
Michael Ward	Managing Director, Raytheon Australia

EXPERT INDUSTRY PANEL MEETINGS

Date	Location
30 May 2012	Australian Parliament House, Canberra, ACT
14 August 2012	Forgacs Engineering, Newcastle, NSW
11 September 2012	Raytheon Australia, Macquarie Park, NSW
13 November 2012	BAE Systems Australia, Canberra, ACT
15 February 2013	BAE Melbourne Shipyard, Williamstown, VIC

SUBMISSIONS AND CONSULTATION

Advanced Manufacturing CRC
ASC
Austal
Australian Industry and Defence Network
Australian Industry Group
Australian Manufacturing Workers Union
Australian Marine Complex, Western Australia
Australian Marine Technologies
Australian Maritime College
BAE Systems Australia
BMT Design and Technology
Boeing Defence Australia
DCNS
Deep Blue Tech
Defence Materials Technology Centre
Defence SA
Defence Teaming Centre
Department of Immigration and Citizenship
Department of Industry, Innovation, Science, Research and Tertiary Education
Electric Boat
Engineers Australia
HunterNet Co-operative
Institute of Marine Engineering, Science and Technology
J&H Williams
Lockheed Martin
Navantia
New South Wales, Department of Trade and Investment
Raytheon Australia
Royal Institute of Naval Architects
SAAB Systems Australia
SonarTech Atlas
South Australia, Department of Further Education, Employment, Science and Technology
Thales Australia
University of South Australia

ANNEX C

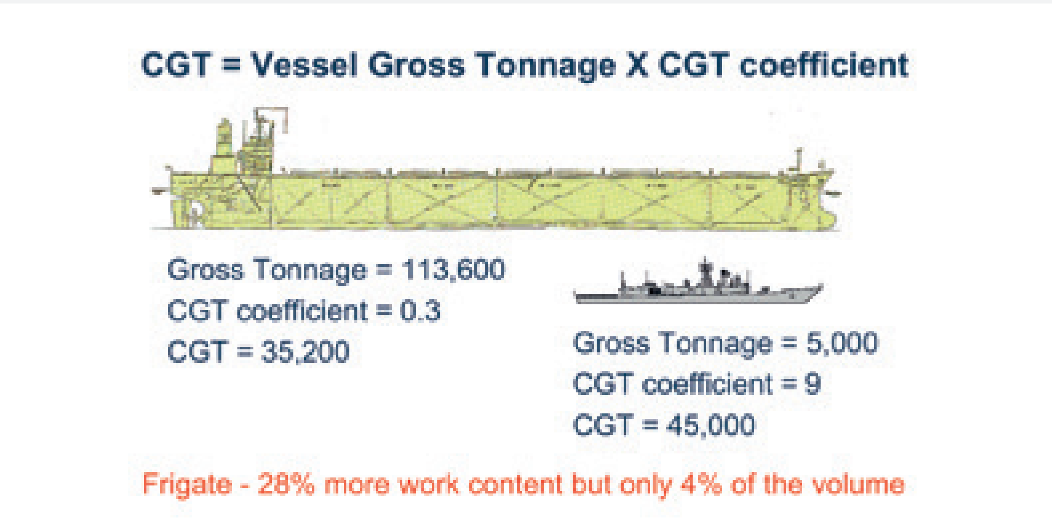
SHIPYARD WORKFORCE SCENARIOS

The workforce scenarios presented here are representations of the workforce numbers that may be required by shipyards to build the types of ships that have been proposed in the 2009 Defence White Paper and the Defence Capability Plan 2011 and 2012.

A formula has been developed by First Marine International to compare the amount of work required to construct different vessels. There are two major variables: the first is a ship's gross tonnage (GT) figure which is a measure of the ship's internal volume. It is not the same as a ship's displacement or dead weight. The second is the 'CGT coefficient' that represents the complexity of the vessel design and allows a comparison to be made across different types of vessels: a tanker, while large, is a relatively simple design and so will have a much lower CGT coefficient compared to a modern complex warship. Multiplying the Gross Tonnage by the CGT coefficient produces a figure for Compensated Gross Tonnage (CGT) and it is this figure that allows a comparison of the relative amount of work required to build different vessels. See figure C.1 below and Craggs, et al 2004 for a detailed description of the methodology.

CGT coefficients are based on typical commercial contracts which require little external oversight but naval design and construction projects require the shipbuilder to commit proportionately more management, technical and administrative resources as the customer requires the shipbuilder to adopt practices for warships not required in commercial shipbuilding. This additional effort needs to be taken into account so the CGT coefficient is adjusted accordingly with a correction called the customer factor.

FIGURE C.1: CGT COMPARISON



The estimates of ship dimensions, gross tonnage figures, CGT coefficients and customer factors made by First Marine International and used in developing these workforce scenarios are shown in figure C.2.

FIGURE C.2: MARITIME PROJECTS UNDER CONSIDERATION

	NO.	ESTIMATED DIMENSIONS
SEA 1000 SUBMARINES	12	Length: c 80 m GT: over 800 CGT coefficient: 55 Customer Factor: 1.15 CGT: over 51,000
SEA 1180 OFFSHORE PATROL	20	Length: c 90 m GT: over 3,300 CGT coefficient: 9 Customer Factor 1.1 CGT: over 32,000
SEA 1654 SUPPLY VESSELS	2	Length: c 170 m GT: over 16,000 CGT coefficient: 2.5 Customer Factor 1.07 CGT: over 43,000
SEA 5000 FRIGATES*	8	Length: c 150 m GT: over 7,000 CGT coefficient: 7.6 Customer Factor 1.1 CGT: over 62,000
JP2048 PH 5 HEAVY LANDING CRAFT	6	Length: c 65 m GT: over 2,000 CGT coefficient: 2.68 Customer Factor 1.07 CGT: over 5,000
ICEBREAKER	1	Length: c 90 m GT: over 4,000 CGT coefficient: 2.8 Customer Factor 1.07 CGT: over 11,000

Once the CGT data has been determined, the number of hours required to build a ship can then be calculated by multiplying the vessel's CGT by shipyard productivity, described in terms of man-hours per CGT. First Marine International has made an assessment of the productivity of the major Australian shipyards working on the Air Warfare Destroyer project, and while productivity is currently low, it is expected to improve to a target rate of 80 man hours/CGT. It was also determined that the shipyards could achieve a better productivity rate, based on their layout, infrastructure and work practices, and takes into account an experienced workforce working with a mature ship design, with minimal changes. Core (normal) productivity, however, would not be expected to be achieved until at least the fourth ship of a production run.

To complete the workforce profile for each project, the build schedule needs to be determined, with estimates made of the length of time required to build one vessel as well as the rate at which the ships are produced, the keel interval as it is called. It is these two variables that produce the production 'drumbeat', the rate of work in the shipyard. Changing either the build time or the keel interval will affect number of workers required: a quicker drumbeat will obviously require more workers to keep up the pace, while a slower rate will need fewer people in the shipyards.

The date when each project starts is based on information outlined in the most recent public version of the Defence Capability Plan (Defence Capability Plan 2012). It provides dates for important milestones in each project's schedule. In terms of production, the important ones are the 'Year of Decision' (also called Second Pass) which gives the final approval for the project and the Initial Materiel Release (IMR) date, when production has finished, the vessel is launched and is available for testing. See figure C.3 over leaf.

FIGURE C.3: DEFENCE CAPABILITY PLAN SCHEDULES

VESSEL TYPE	DEFENCE CAPABILITY PLAN 2012 PROJECT SCHEDULES (FY)			
	FIRST PASS APPROVAL	YEAR OF DECISION	INITIAL MATERIEL RELEASE	INITIAL OPERATIONAL CAPABILITY
HEAVY LANDING CRAFT	2013/14 to 2014/15	2017/18 to 2020/21	2020/21 to 2022/23	2022/23 to 2023/24
FUTURE SUBMARINES	2013/14 to 2014/15	2016/17 to 2017/18	2019/20 to 2025/26	2025/26 to 2026/27
OFFSHORE PATROL	2014/15 to 2015/16	2016/17 to 2019/20	2017/18 to 2021/22	2018/19 to 2020/21
SUPPLY SHIP	2012/13 to 2013/14	2014/15 to 2017/18	2018/19 to 2020/21	2018/19 to 2022/23
FUTURE FRIGATES*	2018/19 to 2020/21	2021/22 to 2023/24	2026/27 to 2028/29	2027/28 to 2029/30
ICE BREAKER	Not included in DCP 2012			

** Note: the schedule provided in the Defence Capability Plan 2012 for SEA 5000 Future Frigate refers only to Phase 1A of the project, the development of a high-power phased array radar demonstrator. The schedule dates used above are from the Defence Capability Plan 2011.*

ASSUMPTIONS

The scenarios shown here are based on the following assumptions:

1. The AWD, LHD and Cape class workforce profiles are based on actual data and workforce projections. Workforce profiles for future projects are based on the typical shipbuilding project profiles.
2. The scenarios presented show the total workforce numbers required for projects in the Defence Capability Plan and selected other Government shipbuilding projects. This analysis does not infer that all such work will be done in Australia.
3. The vessels will be built to either an existing or Australianised Military Off-The-Shelf (MOTS) design. If a new design was being considered, much more time between Second Pass and start of construction will be required.
4. Gross Tonnage figures are estimates made by First Marine International based on current naval vessels that fit the general description of the capabilities outlined in the Defence White Paper 2009 and the Defence Capability Plan 2012.
5. Values for the CGT Coefficients and Customer Factors are based on advice from First Marine International.
6. Important decision dates for the maritime projects are based on the Defence Capability Plan, the 2011 version for Scenario 1 and the 2012 public version for the scenarios after that. It is assumed that decisions will be made early in the range listed.
7. One year from the Second Pass decision date has been allowed for production engineering and other start up activities before start of fabrication. Experience shows that more than one year may be required.

8. The length of the construction phase takes account of the time taken to build each vessel and the keel to keel interval.
9. The shipyard workforce numbers calculated in these scenarios are for production workers (blue collar) and supervisors including production engineers (white collar). It does not include the design team, combat or platform system engineering staff.
10. Productivity is calculated as Man-Hours/Compensated Gross Tonnage (Man-Hours/CGT).
11. The workforce projections have been determined on a base productivity level of 80 man-hours/CGT. A high level of productivity is assessed at 50 man-hours/CGT, while a low level of productivity is 110 man-hours/CGT.
12. The average shipyard worker works 2000 hours/year which includes an allowance for typical overtime worked.

THE SCENARIOS

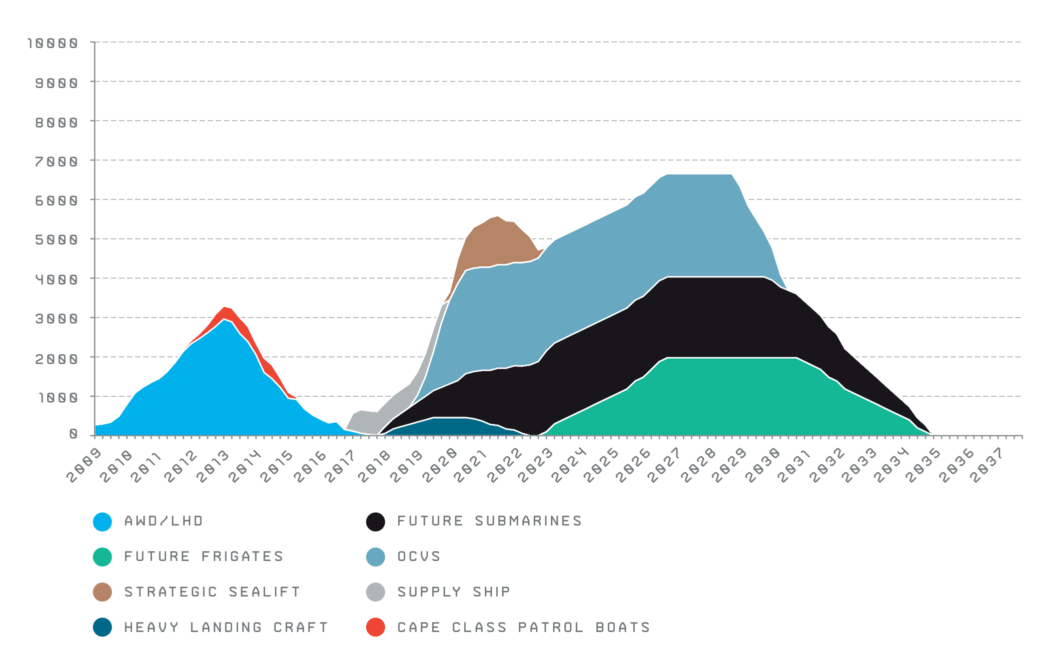
A selection of possible shipyard workforce scenarios is presented in this section. Given the number of variables, it would be impossible to present every permutation here. Projects can be brought forward or postponed; it may be decided that some ships could be built wholly overseas or as a hybrid local/offshore program; construction programs may be accelerated or lengthened by changing either the build schedule for the vessel or the keel interval between ships. Capability requirements for certain vessels may change. An experienced workforce will become more productive and efficient.

One change to any shipbuilding project will vary the overall shipyard numbers needed to complete the projects, and as seen in these scenarios, a combination of changes can produce dramatic effects in workforce requirements.

The scenarios are presented as a set to give an indication of the sorts of changes that might be possible. The scenarios are deliberately not presented with an extensive analysis of the advantages or disadvantages of each or any indication of specific preferred options.

In general terms, the objective of such a rearrangement is to optimise the pattern of work for the industry in order to improve proficiency and increase productivity: independently considering all the major skill sub-groups in the systems architecting, production engineering, and production workforces. An example of the sort of profile that moves towards that goal is scenario 16. This scenario features staggered project start dates, longer build programs and longer keel intervals that promote skills development, facilities investment, more stable and sustainable workforces, opportunity to grow experience, and so on. This in turn improves workforce proficiency and productivity, develops better anticipation and avoidance of problems and ultimately lower costs and more reliable schedules. The scenarios do not show the 'learning curve' effect on productivity levels that that would come from a long term rolling build program.

SCENARIO 1: DEFENCE CAPABILITY PLAN 2011



BASELINE ASSUMPTIONS:

Target productivity of 80 man-hours/CGT.

Air Warfare Destroyer/Landing Helicopter Dock: Production schedule as of May 2011.

Cape Class Patrol Boats: Production starts 2011, 18 months build per boat, three month keel interval.

Future Frigates: Second Pass 2022; Production starts 2023; five years build per ship, one year keel interval.

Heavy Landing Craft (LCH): Second Pass 2017; Production starts 2018; two years build per vessel, six month keel interval.

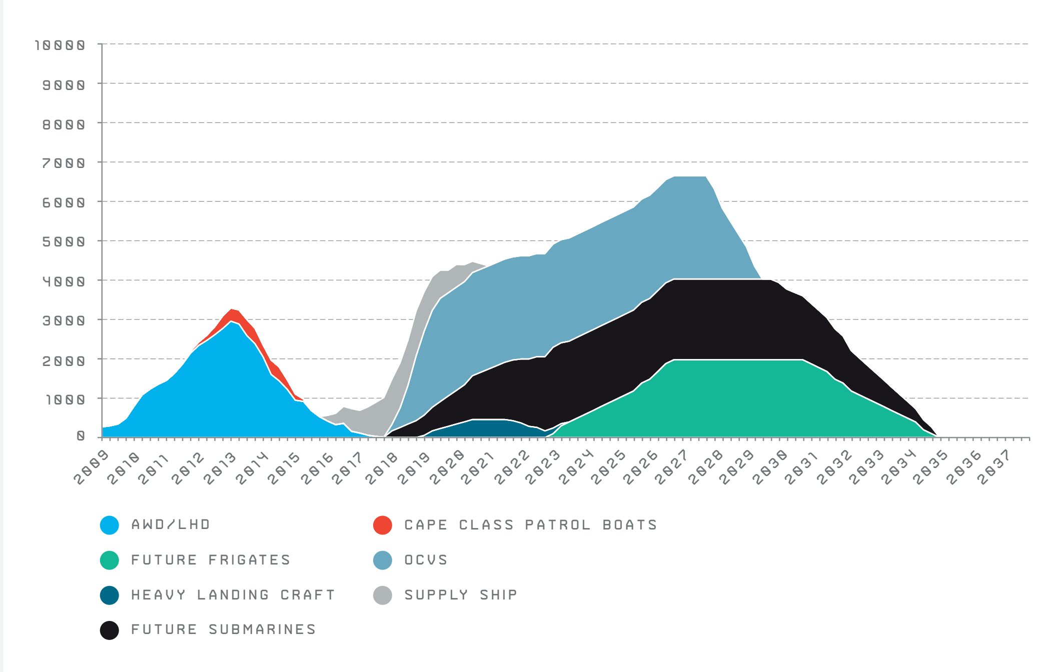
Future Submarines: Second Pass 2017; Production starts 2018; six years build per boat, one year keel interval.

Offshore Combatant Vessels: Second Pass 2018; Production starts 2019; two years build per vessel, six month keel interval.

Supply ship: Second Pass 2016; Production starts 2017; three year build schedule.

Strategic Sealift: Second Pass 2019, Production starts 2020; three year build schedule.

SCENARIO 2: DEFENCE CAPABILITY PLAN 2012



BASELINE ASSUMPTIONS:

Target productivity of 80 man-hours/CGT.

Air Warfare Destroyer/Landing Helicopter Dock: Production schedule as of May 2011.

Cape Class Patrol Boats: Production starts 2011, 18 months build per boat, six month keel interval.

Future Frigates: Second Pass 2022; Production starts 2023; five years build per ship, one year keel interval.

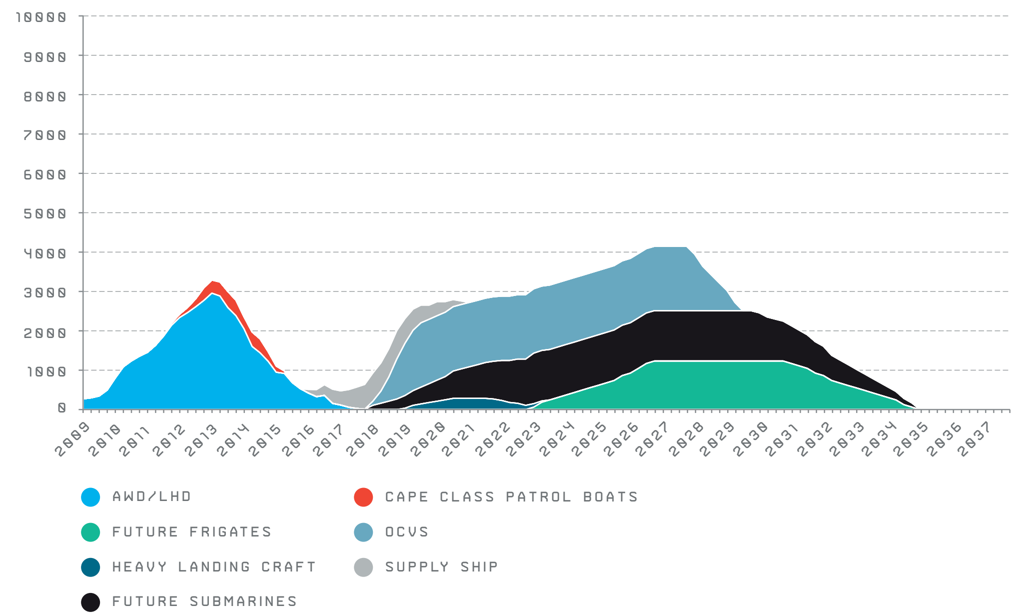
Heavy Landing Craft (LCH): Second Pass 2018; Production starts 2019; two years build per vessel, six month keel interval.

Future Submarines: Second Pass 2017; Production starts 2018; six years build per boat, one year keel interval.

Offshore Combatant Vessels: Second Pass 2017; Production starts 2018; two years build per vessel, six month keel interval.

Supply ships: Second Pass 2015; Production starts 2016; three years build per ship, 2 year keel interval.

SCENARIO 3: DEFENCE CAPABILITY PLAN 2012; EFFECT OF HIGH PRODUCTIVITY

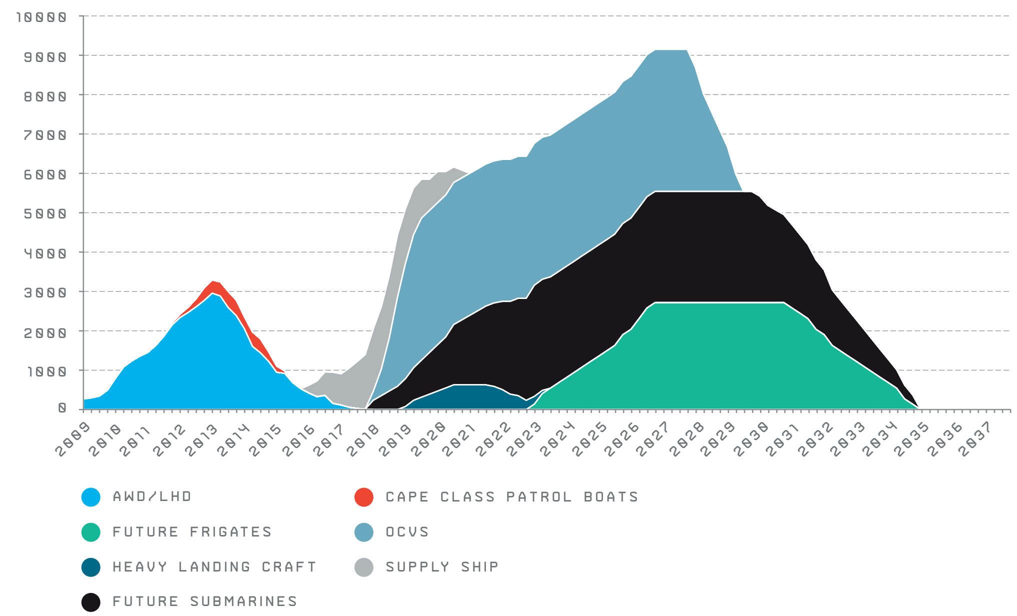


CHANGES:

Same as Scenario 2, except for:

High productivity of 50 man-hours/CGT.

SCENARIO 4: DEFENCE CAPABILITY PLAN 2012; EFFECT OF LOW PRODUCTIVITY

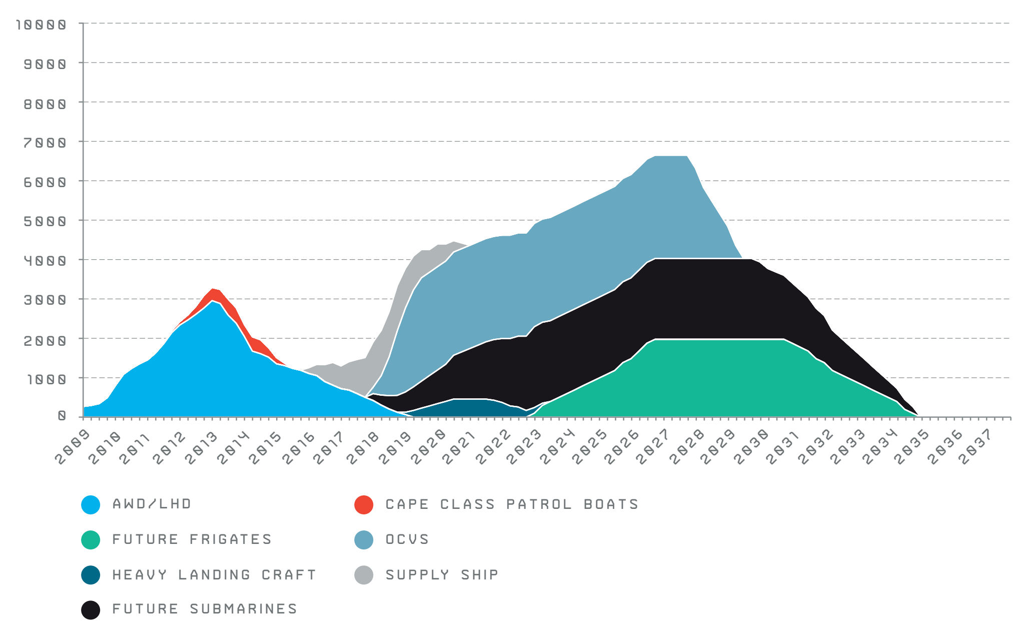


CHANGES:

Same as Scenario 2, except for:

Low productivity of 110 man-hours/CGT.

SCENARIO 5: DEFENCE CAPABILITY PLAN 2012; REBASELINED AWD SCHEDULE



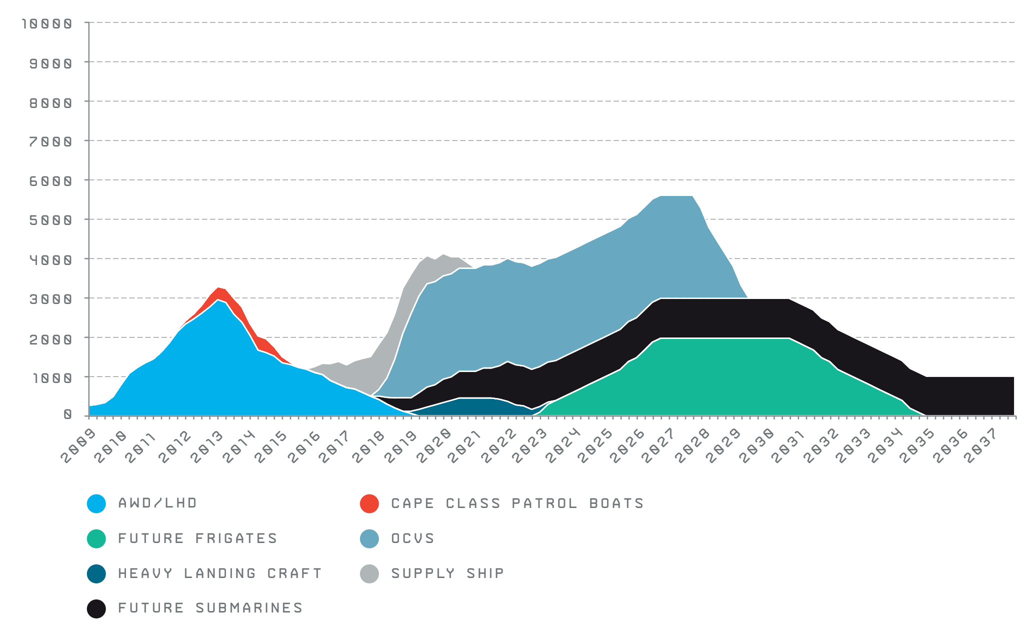
CHANGES:

Same as Scenario 2, except for:

Air Warfare Destroyer/Landing Helicopter Dock: Rebaselined AWD Production schedule as announced September 2012. Six years build per ship, one and a half year keel interval.

This represents the current forecasted schedule for the acquisition of Defence maritime projects.

SCENARIO 6: DEFENCE CAPABILITY PLAN 2012; ROLLING BUILD PROGRAM FOR FUTURE SUBMARINES

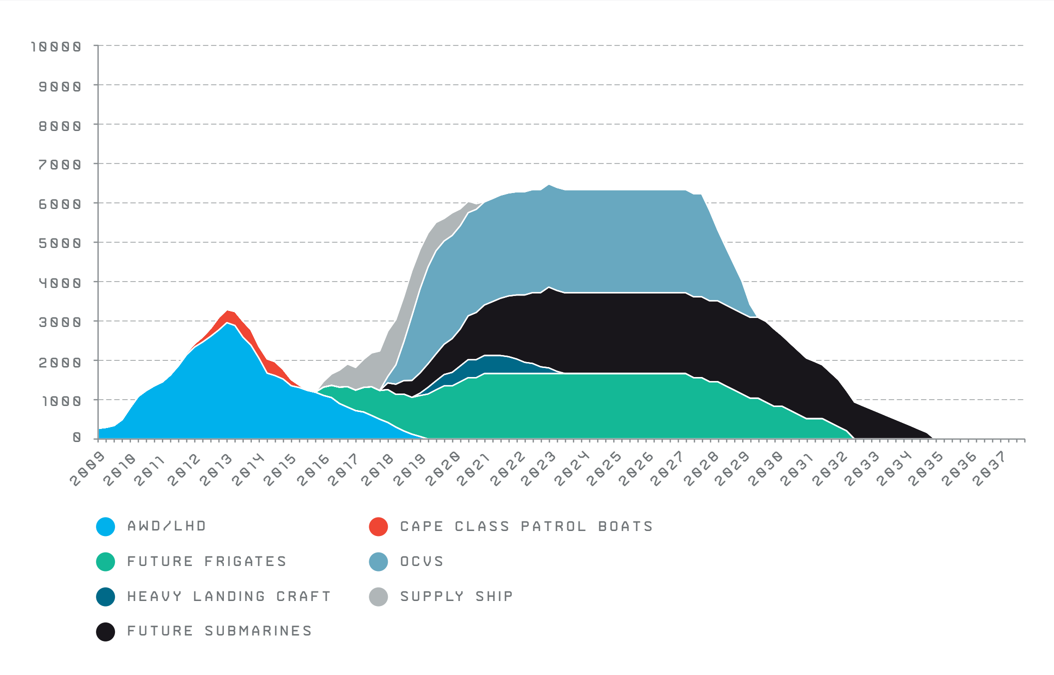


CHANGES:

Same as Scenario 5, except for:

Future Submarines: Second Pass 2017; Production starts 2018; six years build per boat, two year keel interval.

SCENARIO 7: DEFENCE CAPABILITY PLAN 2012; CONNECTED BUILD PROGRAM FOR FUTURE FRIGATES WITH 18 MONTH KEEL INTERVAL

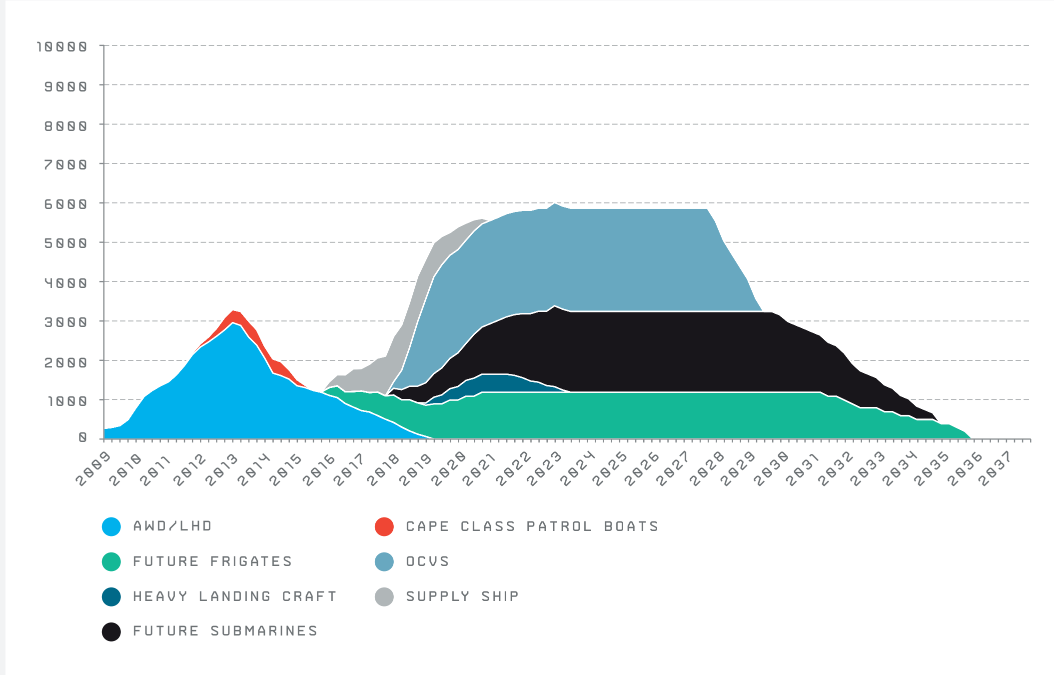


CHANGES:

Same as Scenario 5, except for:

Future Frigates: Based on the Air Warfare Destroyer hull and built as a connected program. Production starts 2016; six years build per ship, one and a half year keel interval.

SCENARIO 8: DEFENCE CAPABILITY PLAN 2012; CONNECTED BUILD PROGRAM FOR FUTURE FRIGATES WITH TWO YEAR KEEL INTERVAL

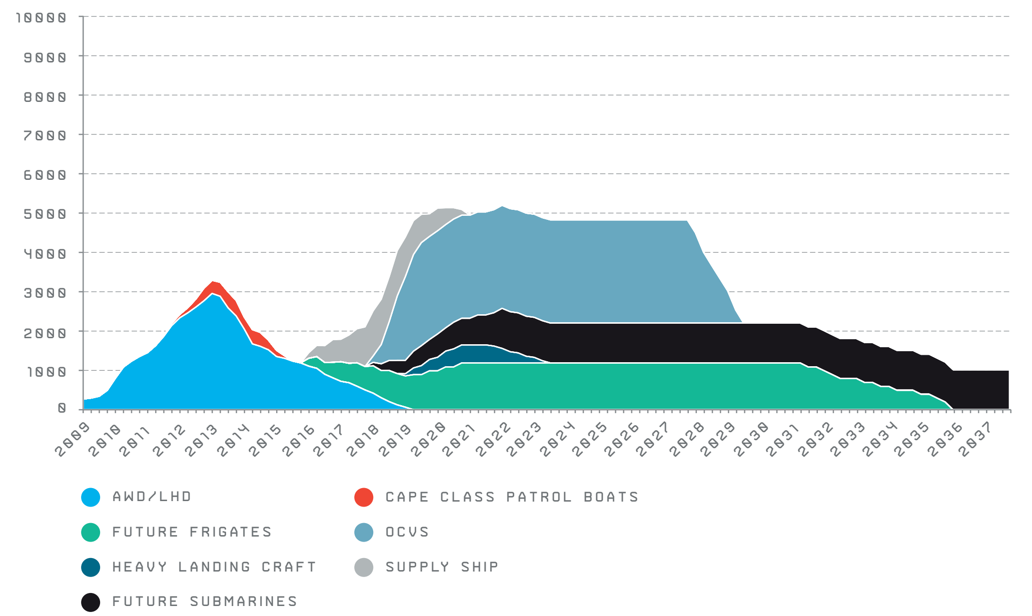


CHANGES:

Same as Scenario 7, except for:

Future Frigates: Based on the Air Warfare Destroyer hull and produced in a rolling build program. Production starts 2016; six years build per ship, two year keel interval.

SCENARIO 9: DEFENCE CAPABILITY PLAN 2012; CONNECTED BUILD PROGRAM FOR FUTURE FRIGATES WITH TWO YEAR KEEL INTERVAL, ROLLING BUILD FOR FUTURE SUBMARINES

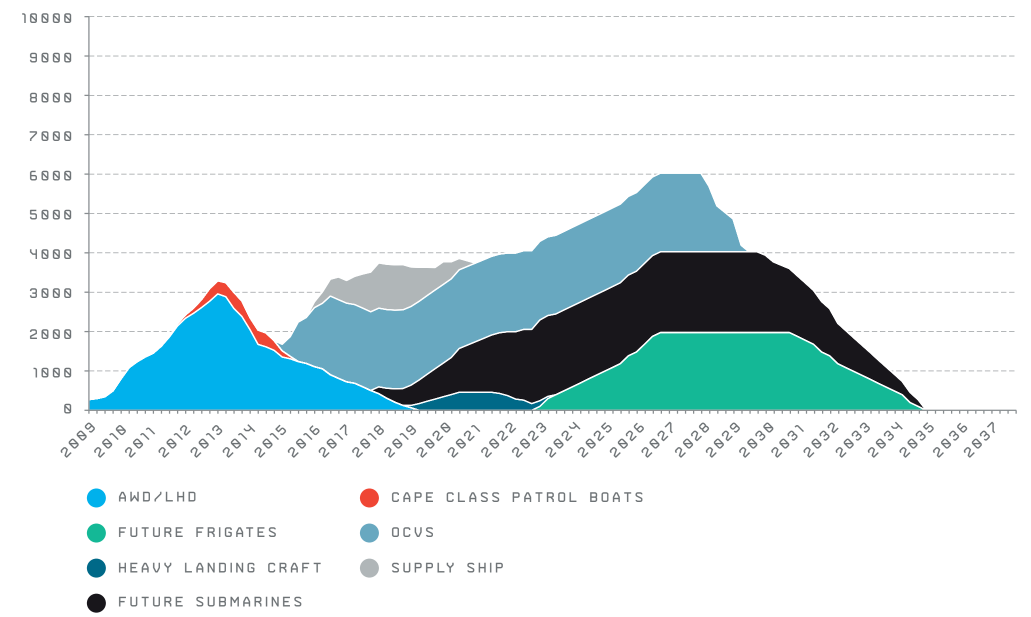


CHANGES:

Same as Scenario 8, except for:

Future Submarines: Second Pass 2017; Production starts 2018; six years build per boat, two year keel interval.

SCENARIO 10: DEFENCE CAPABILITY PLAN 2012; OFFSHORE COMBATANTS MOVED FORWARD IN SCHEDULE

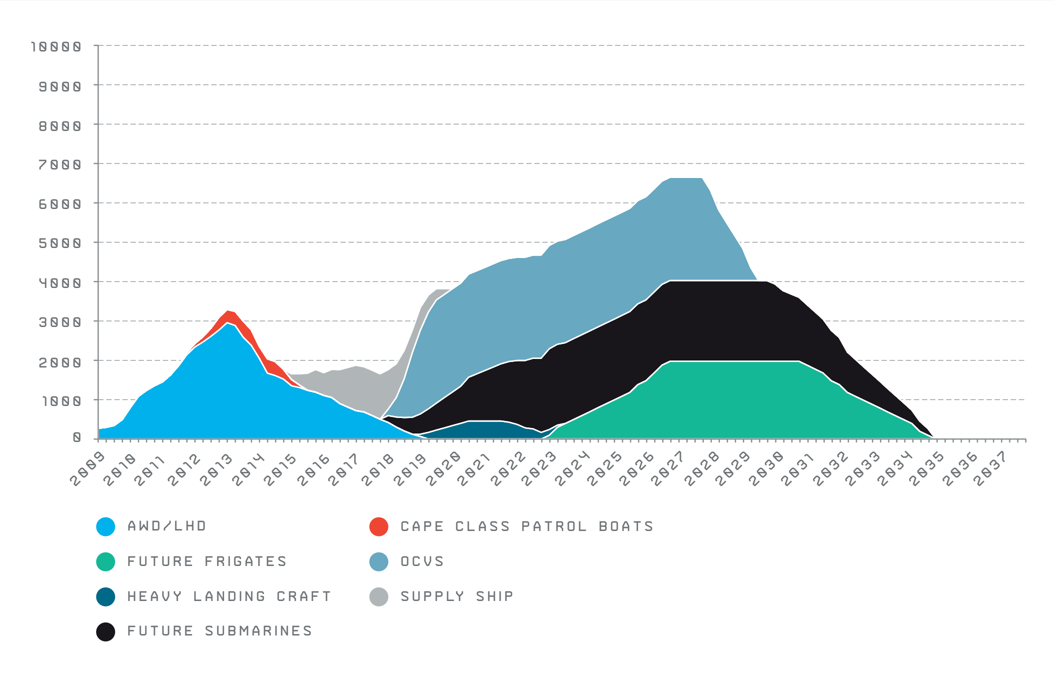


CHANGES:

Same as Scenario 5, except for:

Offshore Combatant Vessels: Moved forward three years. Second Pass 2014; Production starts 2015; two years build per vessel, nine month keel interval.

SCENARIO 11: DEFENCE CAPABILITY PLAN 2012; SUPPLY SHIPS MOVED FORWARD IN SCHEDULE

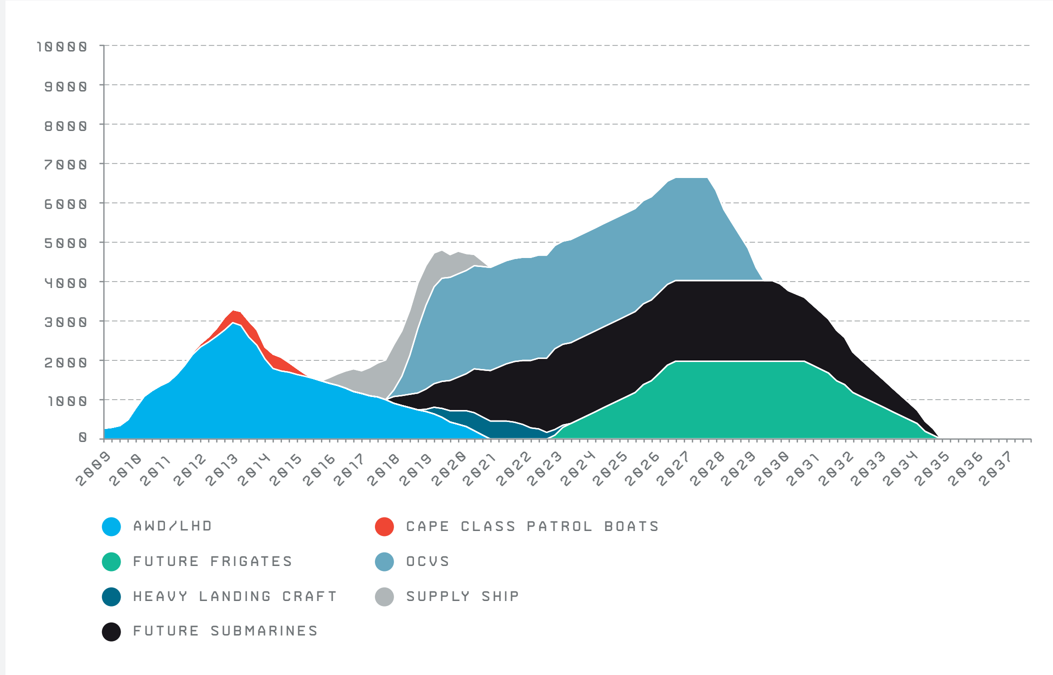


CHANGES:

Same as Scenario 5, except for:

Supply ships: Moved forward one year. Second Pass 2014; Production starts 2015; three years build per ship, 2 year keel interval.

SCENARIO 12: DEFENCE CAPABILITY PLAN 2012; FOURTH SHIP ADDED TO AWD FABRICATION SCHEDULE

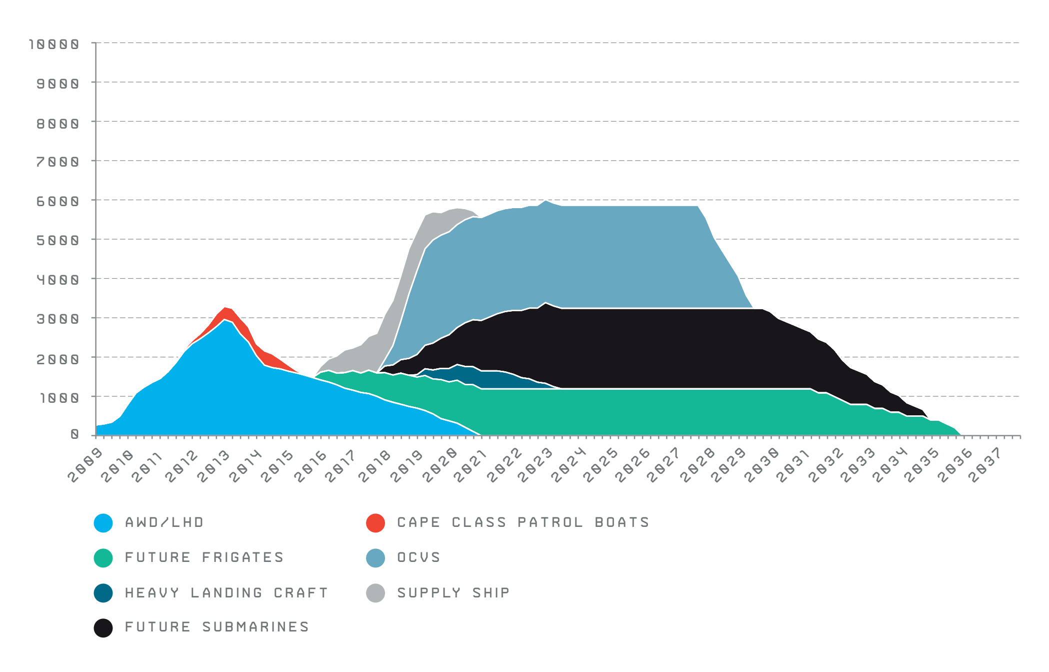


CHANGES:

Same as Scenario 5, except for:

Air Warfare Destroyer/Landing Helicopter Dock: Rebaselined AWD Production schedule as announced September 2012. Fourth AWD added, Production begins 2016, six years build per vessel, one and a half year keel interval.

SCENARIO 13: DEFENCE CAPABILITY PLAN 2012; FOURTH SHIP ADDED TO AWD FABRICATION SCHEDULE

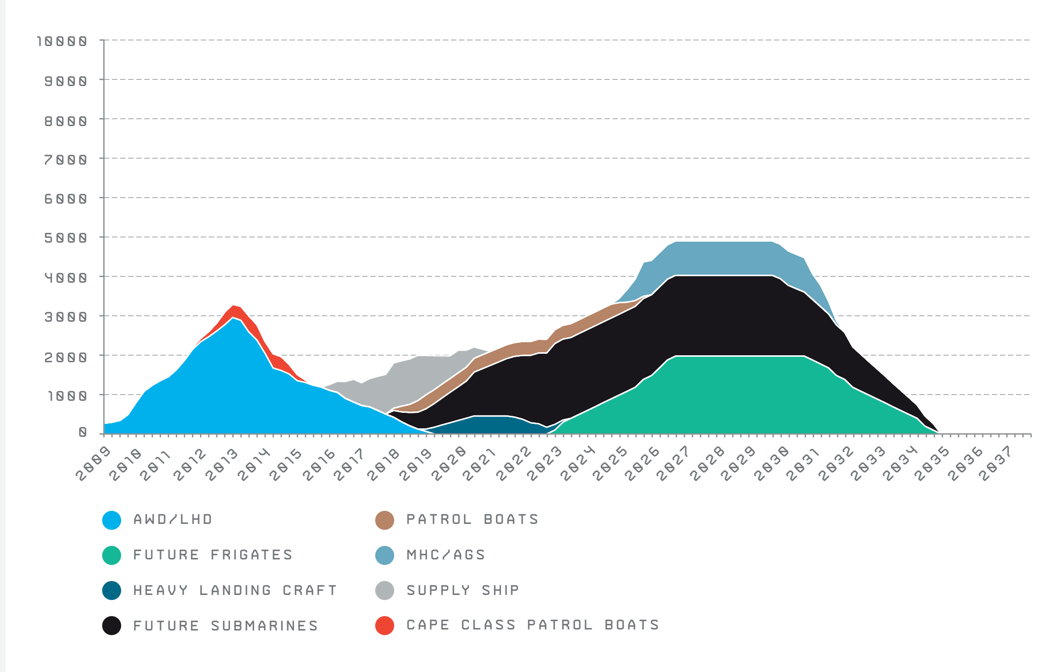


CHANGES:

Same as Scenario 12, except for:

Future Frigates: Based on the Air Warfare Destroyer hull and produced in a rolling build program. Production starts 2016; six years build per ship, two year keel interval.

SCENARIO 14: DEFENCE CAPABILITY PLAN 2012; CHANGE TO CAPABILITY REQUIREMENTS FOR OFFSHORE COMBATANTS

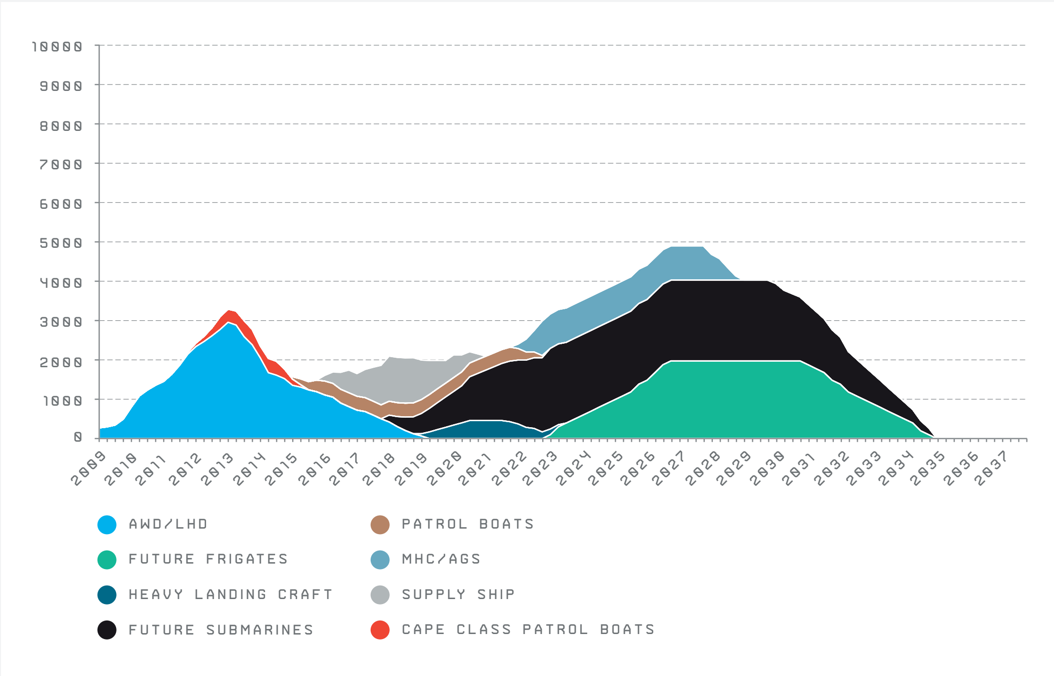


CHANGES:

Same as Scenario 5, except for:

Offshore Combatant Vessels: Change from single multi-mission vessel to separate Patrol Boat and Minehunter/Survey vessels. Patrol Boats: Production starts 2018; one and half years build per vessel, six month keel interval. Minehunter/Survey Vessels: Production starts 2025; two years build per vessel, one year keel interval.

SCENARIO 15: DEFENCE CAPABILITY PLAN 2012; CHANGE TO CAPABILITY REQUIREMENTS FOR OFFSHORE COMBATANTS AND BROUGHT FORWARD THREE YEARS

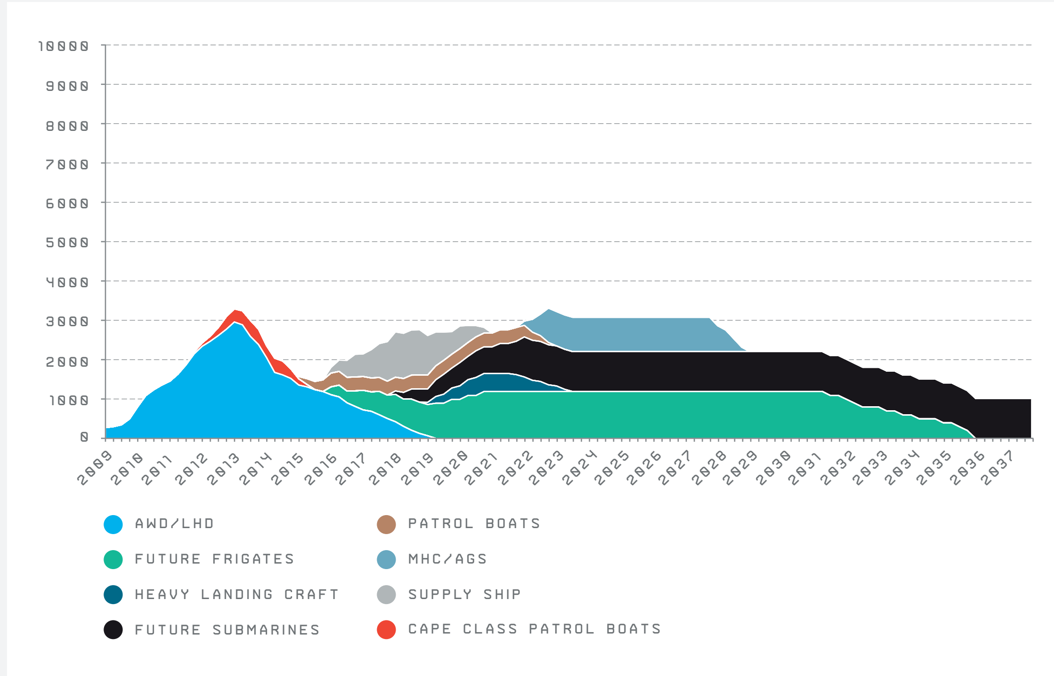


CHANGES:

Same as Scenario 14, except for:

Offshore Combatant Vessels: Change from single multi-mission vessel to separate Patrol Boat and Minehunter/ Survey vessels; and bring forward three years. Patrol Boats: Production starts 2015; one and half years build per vessel, six month keel interval. Minehunter/Survey Vessels: Production starts 2022; two years build per vessel, one year keel interval.

SCENARIO 16: DEFENCE CAPABILITY PLAN 2012; CAPABILITY REQUIREMENTS FOR OFFSHORE COMBATANTS CHANGED AND BROUGHT FORWARD IN THE SCHEDULE, CONNECTED BUILD PROGRAM FOR FUTURE FRIGATES WITH TWO YEAR KEEL INTERVAL, ROLLING BUILD FOR FUTURE SUBMARINES



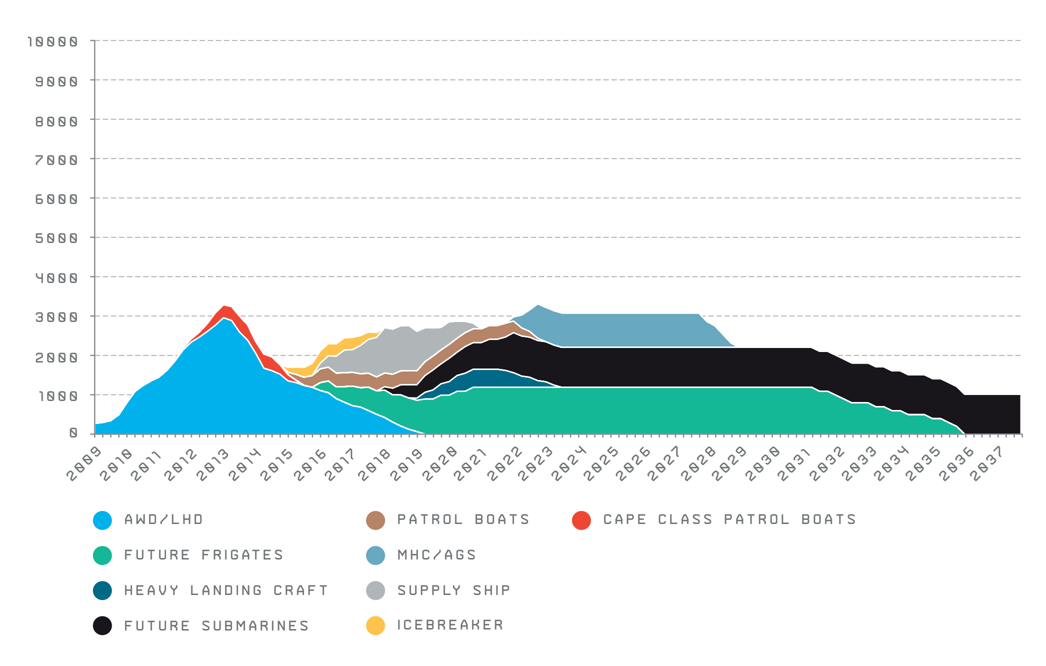
CHANGES:

Same as Scenario 15, except for:

Future Submarines: Second Pass 2017, Production starts 2018; six years build per boat, two year keel interval.

Future Frigates: Based on the Air Warfare Destroyer hull and produced in a rolling build program. Production starts 2016; six years build per ship, two year keel interval.

SCENARIO 17: DEFENCE CAPABILITY PLAN 2012; CAPABILITY REQUIREMENTS FOR OFFSHORE COMBATANTS CHANGED AND BROUGHT FORWARD IN THE SCHEDULE, FOURTH AWD, CONNECTED BUILD PROGRAM FOR FUTURE FRIGATES WITH TWO YEAR KEEL INTERVAL, ROLLING BUILD FOR FUTURE SUBMARINES, ICEBREAKER ADDED

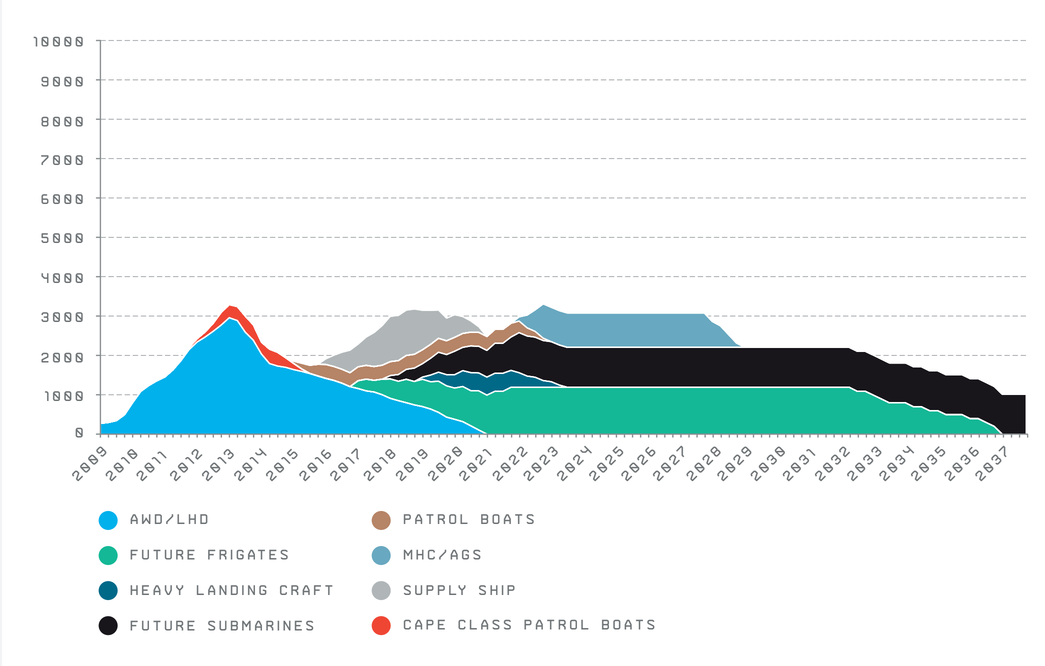


CHANGES:

Same as Scenario 16, except for:

Icebreaker: Production starts 2015; three years build per ship.

SCENARIO 18: DEFENCE CAPABILITY PLAN 2012; CAPABILITY REQUIREMENTS FOR OFFSHORE COMBATANTS CHANGED AND BROUGHT FORWARD IN THE SCHEDULE, FOURTH AWD, CONNECTED BUILD PROGRAM FOR FUTURE FRIGATES WITH TWO YEAR KEEL INTERVAL, ROLLING BUILD FOR FUTURE SUBMARINES



CHANGES:

Same as Scenario 16, except for:

Air Warfare Destroyer/Landing Helicopter Dock: Rebaselined AWD Production schedule as announced September 2012. Fourth AWD added, Production begins 2016, six years build per vessel, one and a half year keel interval.

Future Frigates: Based on the Air Warfare Destroyer hull and produced in a rolling build program. Production starts 2017; six years build per ship, two year keel interval.

ANNEX D

SELECT BIBLIOGRAPHY

ACIL 2001	*Economic impact of defence: Vol 1: main report*, ACIL Consulting, 2001.
ACIL 2005	*Skills shortages and the amphibious ships project*, ACIL Tasman, 2005.
ACIL 2009	*The economic impacts of the Bushranger project*, ACIL Tasman, 2009.
ANAO 57	*Auditor General Audit Report No 57, Acceptance into Service of Navy Capability*, Commonwealth of Australia, 2011.
ASC 2006	*Improving the cost-effectiveness of naval shipbuilding in Australia*, Submission by ASC to the Senate Standing Committee on Foreign Affairs, Defence and Trade, 2006.
ASPI 2002	*Setting a course for Australia's naval shipbuilding and repair industry*, Mark Thomson and Sam Harrington, Policy Report, Australian Strategic Policy Institute, 2002.
ASPI PA16	*Keeping our heads below water: Australia's future submarine*, Andrew Davies, Policy Analysis 16, Australian Strategic Policy Institute, 2008.
ASPI SI4	*Weapons of mass construction: Australian naval shipbuilding*, Mark Thomson, Strategic Insight 4, Australian Strategic Policy Institute, 2004.
ASPI SI22	*Cutting edge: the Collins experience*, Patrick Walters, Strategic Insight 22, Australian Strategic Policy Institute, 2009.
ASPI SI48	*How to buy a submarine: defining and building Australia's future fleet*, Sean Costello and Andrew Davies, Strategic Insight 48, Australian Strategic Policy Institute, 2009.
ASPI SI57	*Mind the gap: getting serious about submarines*, Andrew Davies and Mark Thomson, Strategic Insights 57, Australian Strategic Policy Institute, 2012.
ASPI SR25	*We'll have six of them and four of those: off-the-shelf procurement and its strategic implications*, Andrew Davies and Peter Layton, Strategic Report 25, Australian Strategic Policy Institute, 2009.
ASPI SR31	*Naval gazing: the future of Australia's naval shipbuilding and repair sector*, Andrew Davies, Strategic Report 31, Australian Strategic Policy Institute, 2010.
ASPI PA78	*The once and future submarine—raising and sustaining Australia's underwater capability*, Andrew Davies, Policy Analysis 78, Australian Strategic Policy Institute, 2011.
ASPI PA93	*Subaqueana australis-the future evolution of Australia's submarines*, Andrew Davies, Policy Analysis 93, Australian Strategic Policy Institute, 2012.
ASPI PA99	*What price the future submarine?*, Andrew Davies, Policy Analysis 99, Australian Strategic Policy Institute, 2012.
ASPI Paper 2012	*Should Australia build warships?: an economic and strategic analysis*, Andrew Davies, Henry Ergas and Mark Thomson, Discussion Paper, Australian Strategic Policy Institute, 2012.
Barrie 2009	'The Defence White Paper 2009 and Australia's maritime capabilities', Chris Barrie, *Security Challenges* 5.2, Winter 2009.
Coles 2011	*Collins class sustainment review; Phase 1 report*, John Coles et al, Commonwealth of Australia, 2011.
Coles 2012	*Study into the business of sustaining Australia's strategic Collins class submarine capability*, John Coles et al, Commonwealth of Australia, 2012.
Craggs et al 2004	'Naval Compensated Gross Tonnage coefficients and shipyard learning', John Craggs et al., *Journal of Ship Production*, Volume 20, Number 2, May 2004.
DeakinPrime 2011	*Defence Materiel Organisation: Future Submarine Training Feasibility Study*, DeakinPrime 2011.
Defence SA 2009	*Naval Shipbuilding: Australia's $250 Billion Nation Building Opportunity*, Defence SA Advisory Board, 2009.
DCP2012	*Defence Capability Plan 2012*, Commonwealth of Australia, 2012.
Engineers Australia 2006	*Naval shipbuilding in Australia*, Submission by Engineers Australia to the Senate Standing Committee on Foreign Affairs, Defence and Trade, 2006.
GAO-10-522	*Strong leadership is key to planning and executing stable weapon programs*, US Government Accountability Office, 2010.
GSIBBS 1	*Global shipbuilding industrial base benchmarking study, part 1: major shipyards*, US Department of Defense, 2005.
GSIBBS 2	*Global shipbuilding industrial base benchmarking study, part 2: mid-tier shipyards*, US Department of Defense, 2005.
Guarding Our Edge	*Guarding our edge: building and sustaining the future submarine in Australia*, Defence SA Advisory Board, 2012.
Kokoda KP17	*Sub judice: Australia's future submarine*, Kokoda Paper 17, Brice Pacey, Kokoda Foundation, 2012.
NSR 2002	*The Australian naval shipbuilding and repair sector strategic plan*, Commonwealth of Australia, 2002.
RAND CT-259	*Trends in the United Kingdom's naval shipbuilding industrial base: lessons for the United States*, RAND CT-259, John F Schank, RAND Corporation 2006.
RAND MG-236	*Differences between military and commercial shipbuilding*, RAND MG-236-MOD, John Birkler et al., RAND Corporation 2005.
RAND MG-294	*The United Kingdom's naval shipbuilding industrial base: the next fifteen years*, RAND MG-294-MOD, Mark V Arena et al., RAND Corporation 2005.

RAND MG-326/1	*The United Kingdom's nuclear submarine industrial base, Vol 1: sustaining design and production resources*, RAND MG-326/1-MOD, John F Schank et al., RAND Corporation 2005.
RAND MG-484	*Why Has the cost of navy ships risen: a macroscopic examination of the trends in US naval ship costs over the past several decades*, RAND MG-484-NAVY, John F Schank et al., RAND Corporation 2006.
RAND MG-608	*Sustaining US nuclear submarine design capabilities*, RAND MG-608-NAVY, John F Schank et al., RAND Corporation 2007.
RAND MG-725	*Sustaining key skills in the UK naval industry*, RAND MG-725-MOD, Hans Pung et al., RAND Corporation 2008.
RAND MG-991	*Are ships different? Policies and procedures for the acquisition of ship programs*, RAND-911-OSD/NAVY, Jeffrey A Drezner et al., RAND Corporation 2011.
RAND MG-1128	*Learning from experience*, RAND MG-1128-NAVY, John Schank et al., RAND Corporation 2011.
RAND MG-1033	*Australia's submarine design capabilities and capacities*, RAND MG-1033-AUS, John Birkler et al., RAND Corporation 2011.
Roos 2012	*Manufacturing into the future: summary of recommendations*, Göran Roos, Government of South Australia, 2012.
Skills Australia 2012	*Building Australia's defence capabilities*, DIISRTE, Commonwealth of Australia, 2012.
Smarter Manufacturing	*Smarter manufacturing for a smarter Australia: report of the non-government members*, Prime Minister's Taskforce on Manufacturing, Commonwealth of Australia, 2012.
SSCFADT 2006	*Blue water ships: consolidating past achievements*, Report by the Senate Standing Committee on Foreign Affairs, Defence and Trade, Commonwealth of Australia, 2006.
SSCFADT 2012	*Procurement procedures for defence capital projects: final report*, Senate Foreign Affairs, Defence and Trade References Committee, Commonwealth of Australia, 2012.
Tasman 2001	*Impact of major defence projects: a case study of the ANZAC ship project*, Denise Ironfield, Tasman Asia Pacific, 2001.
Tasman 2002	*Impact of major defence projects: a case study of the Minehunter Coastal project*, Tasman Economics, 2002.
Woolner 2009	'Taking the past to the future: The Collins submarine project and SEA 1000', Derek Woolner, *Security Challenges* 5.3, Spring 2009.'
WP2009	*Defending Australia in the Asia Pacific century: Force 2030, Defence White Paper 2009*, Commonwealth of Australia, 2009.
Yule & Woolner 2008	*The Collins Class Submarine Story: Steel, Spies and Spin*, Peter Yule and Derek Woolner, Cambridge University Press, 2008.