NAVAL SHIPBUILDING
Australia’s $250 billion Nation Building Opportunity
ACKNOWLEDGEMENTS

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The last two Defence White Papers (and especially the 2009 White paper) literally wrought a ‘sea change’ in the nation’s defence posture. There has been a reorientation of our maritime capabilities evidenced by such initiatives as the Air Warfare Destroyers, a substantially increased submarine force, a new future class of frigates, an enhanced maritime surveillance capability and a broad step-change in the potency of maritime munitions. This adds up to the most ambitious and significant array of Defence acquisitions since World War II.

We will spend as a nation $250 billion over 30 years on naval ships and submarines – a huge infrastructure project within Australia by any measure. This creates the opportunity, indeed, the need, to revolutionise the efficiency and cost effectiveness of naval shipbuilding and through-life support, and to develop a sustainable national industry and skills capability which will flow through to other ‘high tech’ industries. Apart from cost efficiencies for Defence, the program will be a driver for jobs growth and improved social well being across the nation.

As a leading State in naval ship building and systems engineering, South Australia is committed to ensuring that this vital national project is achieved efficiently and successfully. Over the past 12 months, the Defence SA Advisory Board, in consultation with a broad range of stakeholders, has prepared a discussion paper on naval shipbuilding which explores the fundamental paths to efficiency and cost effectiveness and embraces a ‘whole of nation’ solution.

I commend this paper to you as a key milestone in driving toward a pragmatic and timely outcome.

General Peter Cosgrove AC MC
Chairman
Defence SA Advisory Board
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1.1 **Naval Shipbuilding in Australia**

1.1.1 The intent of this paper is to promote informed discussion about the future of naval shipbuilding in Australia, and particularly ways in which the Australian Government might achieve better value for the military and industrial capability required.

1.1.2 Many things have been written about naval shipbuilding in Australia, ranging from official policy statements through to media commentary. Australia has a good record in naval shipbuilding. Inevitably there have been problems with naval shipbuilding projects, but that is to be expected and should not mask the overall success of these nation-building endeavours. The wide-ranging skills and knowledge developed as a consequence of the COLLINS and ANZAC programs need to be recognised for their ‘nation-building’ outcomes and for their ability to bring Defence, industry, finance and academia together.

1.1.3 There are two primary aspects to the whole subject of naval shipbuilding in Australia; firstly, capability planning, which determines what warships are built and when, and secondly, the performance of Australian industry and major defence projects. Within the broad scope of industry and project performance, the paper will focus on possible future business models with a view to achieving better value in naval shipbuilding. With regard to warship selection, this discussion paper will not review in any detail the steps involved in capability planning, but the paper will examine the dynamic interaction between specific capability choices and industry outcomes.

1.1.4 Typically, when the interaction between capability choice and industry outcomes is discussed, the dominant topics are industry capacity and price estimating (including associated risk). There has been regular conversation about the need for naval capability plans to recognise industry’s capacity, attended by strong argument for smooth loading of industry. Skills shortages are the current aspect of this debate. Price estimating is another facet of the interaction, although this information flow tends to be one-directional with capability planners seeking price estimates to confirm the affordability of plans. This price validation process is very different from the dynamic modelling of different capability-industry options, which more precisely explore the varying impacts on cost, especially long-term total cost of ownership.

1.1.5 There are several reasons why it is worth examining these matters at this time, primarily:

- **Force 2030**, the 2009 Defence White Paper sets out the plan for naval shipbuilding over the next 20 years, which includes 12 submarines, eight frigates, 20 offshore combatant vessels, six heavy landing craft, one strategic sealift ship, and one replenishment and logistic support ship – 48 naval ships in total.

- The increasing pressure on the Australian Government’s Defence budget, particularly in the prevailing global financial crisis.

- The increasing capability and complexity, hence real-term cost of warships.

1.1.6 Ultimately, the objective is for Australia to obtain the military capability it requires, with the knowledge that the method of acquisition and sustainment has been thoroughly understood and carefully designed in order to achieve good value.
1.2 **Purpose**

The purpose of this paper is to promote a broad, relatively detailed discussion about achieving better value in naval shipbuilding in Australia over the next 20 years. The purpose of this paper is not to advocate a choice of warship, or promote a particular industry activity, or confer a competitive advantage on any particular company. Future discussion should involve a broad cross-section of people in Australian and State Governments, and Australian industry, with supporting input from overseas organisations. The ongoing conversation should also encompass some serious analysis and modelling, rather than short and shallow argument.

1.2.2 An underlying motive is that if the short-term and long-term consequences of warship capability and naval shipbuilding industry decisions are more thoroughly understood by all involved in shaping the future, better value can be achieved for the taxpayer and, equally importantly, outcomes become more predictable and stable. In that environment, organisations can implement more assured plans, which attract greater investment and skill formation. As the title of the paper suggests, a clearer understanding of naval shipbuilding can lead to enhanced decision-making, which in turn leads to capability at better value.

1.3 **Scope**

1.3.1 This paper covers a range of topics relevant to naval shipbuilding and the defence programs forecast in the 2009 Defence White Paper (Australian Government, 2009). The paper includes particular coverage of models for naval shipbuilding projects and the interaction between capability choice, and industry performance and cost consequences. Some of the topics aim to present more detail about certain mechanisms and cost drivers in naval shipbuilding; other sections deal with some of the misconceptions that surround the subject.

1.3.2 The discussion paper looks at value in terms of the total cost of ownership of a system, which covers its full life cycle, generally referred to in Defence as acquisition and sustainment.

1.3.3 The term naval shipbuilding is used not in the narrow meaning of steel construction (or other hull material), but to cover all aspects in the acquisition of a warship. With respect to major surface combatants and submarines, this includes combat system integration and naval architecture design; production engineering; project planning and control; equipment and material procurement; hull block fabrication; platform and combat system software and hardware development, set to work, test and trials; certification and delivery.

1.3.4 Although a generic label with universal meaning, for convenience in this paper the term ‘warship’ is used to mean surface combatants such as frigates and destroyers. These are, typically, smaller ships equipped with advanced sensors, different missiles and guns, and a sophisticated combat management system. Submarines, support ships, amphibious ships, patrol boats, hydrographic ships, minehunters and landing craft are the terms used in this paper to describe other naval craft.
1.4 **Audience**

1.4.1 With aims to promote both a broad and relatively detailed discussion on ways to improve value in naval shipbuilding in Australia, this paper is targeted at a knowledgeable audience, but not specialists in the field. The audience includes people in government and industry.

1.5 **Some Definitions**

1.5.1 While this discussion paper does not include an extensive glossary, the usage in this paper of some other common terms warrants some definition:

1.5.1.1 Cost and Price – in this paper, the term cost is used to describe actual resources (money) consumed to create something, whereas price is used to describe the amount charged by the supplier to the customer. An important difference is that price is not always a good indicator of cost, which is where true value must originate. Caution is required in equating the two, especially in historical analysis where data is scarce.

1.5.1.2 Ship Consolidation – this term is used to describe the activity in a shipyard where hull blocks are brought together. The task involves receipt of each block and associated manufacturer’s documentation, inspection, alignment on the main assembly area, joining of the steel structures, installation of any remaining sub-systems, connection of sub-systems, installation of long-run cabling, load out of stores and other consumables, set to work, test and trials (harbour and sea), certification and delivery.

1.5.1.3 Hull Blocks and Modules – block and modular construction are terms commonly used interchangeably to describe this modern method of ship construction. In this paper, the contemporary lexicon of the Air Warfare Destroyer Program is used, where the term block is used to describe the entire portion of a warship hull constructed away from the ship consolidation activity, and a module is a sub-element that is installed inside a block. Modules typically include sub-system equipment: pipe, cabling and ventilation assemblies, etc. The process is described further in Section 12.2.
2.1 The RAN Fleet – Past, Present and Future

2.1.1 Today the Royal Australian Navy (RAN) operates a fleet that includes eight ANZAC and four FFG class warships. Twenty years ago, the RAN operated three DDG, six FFG and five DE class warships. Twenty years into the future, the fleet will include three or four Air Warfare Destroyers (AWD) and eight large anti-submarine frigates. More details are provided in the following tables.

2.2 Defence White Paper 2009 – Future Maritime Capability

2.2.1 The Prime Minister and the Minister for Defence released the 2009 Defence White Paper on 2 May 2009. The paper was entitled Defending Australia in the Asia Pacific Century: Force 2030. As a starting point, the Defence White Paper summarises the requirement for maritime forces as:

Major surface combatants (destroyers and frigates), submarines and other naval capabilities, supported by air combat (for air superiority and maritime strike) and maritime surveillance and response assets, are necessary to establish sea control, and to project force in our maritime environment (including for the purposes of maintaining freedom of navigation, protecting our shipping, and lifting and supporting land forces).

(Australian Government, 2009, page 60)
In the Defence White Paper, the principal tasks for the ADF are decomposed into a set of priority capabilities. The details of the consequent acquisition programs will not be available until subsequent Defence Capability Plans (DCP) are released. The Defence White Paper calls for the acquisition of the following maritime capabilities:

- **Twelve Future Submarines** with greater range, endurance and capability compared to the Collins Class submarines. The new submarines will be ‘assembled in South Australia’, and the construction program ‘will be designed to provide the Government with the option to continue building additional submarines in the 2030s and beyond, should strategic circumstances require it’ (Australian Government, 2009, page 71). The Collins Class is due to be replaced from about 2025, with first of class trials of the future submarine from about 2022.

- **Eight Future Frigates**, ‘which will be larger than the ANZAC class vessels’. The White Paper states ‘The future frigate will be designed and equipped with a strong emphasis on submarine detection and response operations. They will be equipped with an integrated sonar suite that includes long-range active towed-array sonar, and be able to embark a combination of naval combat helicopters and maritime Unmanned Aerial Vehicles (UAV)’ (Australian Government, 2009, page 71). With a service life of 30 years, the ANZAC Class is due to be replaced from about 2026 with first of class trials of the Future Frigate from about 2024.

- **Twenty Offshore Combatant Vessels** ‘which will be larger than the ANZAC class vessels’. The White Paper states ‘The future frigate will be designed and equipped with a strong emphasis on submarine detection and response operations. They will be equipped with an integrated sonar suite that includes long-range active towed-array sonar, and be able to embark a combination of naval combat helicopters and maritime Unmanned Aerial Vehicles (UAV)’ (Australian Government, 2009, page 71). With a service life of 30 years, the ANZAC Class is due to be replaced from about 2026 with first of class trials of the Future Frigate from about 2024.

- **One large strategic sealift ship**, capable of moving stores, equipment and personnel. The ‘new ship will have a displacement of 10,000-15,000 tonnes, with landing spots for a number of helicopters and an ability to land vehicles and other cargo without requiring port facilities’ (Australian Government, 2009, page 73). No in-service date was specified in the Defence White Paper.

- **Six heavy landing craft** ‘with improved ocean-going capabilities, able to transport armoured vehicles, trucks, stores and people in intra-theatre lift tasks to augment the larger amphibious vessels’ (Australian Government, 2009, page 73). No in-service date was specified in the Defence White Paper.

- **One Sea Logistic Support and Replenishment vessel** to replace HMAS Success in 2020 (Australian Government, 2009, page 74).
This capability plan covers the acquisition of 48 naval vessels over the next 20 years. This compares to the acquisition of 40 vessels in the previous 20 years, listed below by commissioning date:

- Eight ANZAC Class frigates from May 1996 to August 2006.
- Six Collins Class submarines from July 1996 to March 2003.
- Fourteen Armidale Class patrol boats from June 2005 to February 2008.
- Six Huon Class minehunters from May 1999 to March 2003.
- Two replenishment vessels, HMAS Westralia in 1989 and HMAS Sirius in 2006.
- Two Leeuwin Class hydrographic vessels in May 2000.

Of the ships listed above, 36 were constructed in Australia, one purchased second-hand from the Royal Navy, two purchased second-hand from the US Navy (then extensively modified in Australia) and one purchased new from a commercial shipyard (then converted for naval use in Australia).

For the ANZAC Ship Project, Tenix also constructed two ships for the Royal New Zealand Navy (commissioned in 1997 and 1999).

The timing and other implementation details for the future programs will be revealed in subsequent Defence Capability Plans. There is also the caveat that some of the vessels may be constructed overseas or procured off a commercial production line. The sealift and support ships are candidates for procurement by this method as was successfully done in 2006 for the replenishment ship HMAS Sirius.

Pursuing Better Value in Future Acquisition Programs

The future naval capability program set down by the 2009 Defence White Paper represents a substantial amount of naval shipbuilding work with an investment in the order of $100 billion. In the White Paper, the Government also endorsed a ‘Strategic Reform Program comprising a comprehensive set of reforms that will fundamentally overhaul the entire Defence enterprise, producing efficiencies and creating savings of about $20 billion.’ Over the next 20 years, the scale of the naval shipbuilding program provides plenty of opportunity to find better value outcomes.
PART I
Warship Costs
3.1 Rising Price of Warships

3.1.1 Research by many organisations, including the Defence Materiel Organisation (DMO), Defence Capability Group and RAND Corporation has shown the price of warships is rising faster than inflation. In 2006, RAND’s research found:

Annual cost escalation rates for amphibious ships, surface combatants, attack submarines, and nuclear aircraft carriers have ranged from seven to 11 per cent in recent decades. This increase has been considerably above general inflation indexes, which have been between four and five per cent per year since 1965. As a result, real annual rates of growth in costs by types of ships the RAND researchers examined have ranged from just under three to just over six per cent. (RAND Corporation 2006, page 1)

3.1.2 RAND observed that these escalation rates were not confined to warships, they are similar to increases in other advanced weapon systems such a fighter aircraft, submarines and armoured vehicles. Defence’s research produced similar findings in respect of rising prices as shown in the following graph.

![Graph showing destroyer and frigate prices](image)

Figure 1: Destroyer and Frigate Prices (Department of Defence)

Real unit prices increasing by 3% pa

3.2 Cause of Rising Prices

3.2.1 There is no single cause for the above-inflation price rise, but the majority of the rise is attributed to customer choices rather than the cost of materials and labour. Customer-driven factors that contribute to rising prices include the demand for larger, more capable warships; modern technology allowing more systems to be packed into a hull; increasing expectations for crew working conditions; and stricter environmental controls. Above-inflation rises in labour costs is also a significant factor.
3.2.2 In RAND’s research it looked at two categories of price rise: economy-driven and customer-driven. Economy-driven prices included labour, material and equipment costs, all dependent upon the general economy rather than government (the RAND term for warship customer). In terms of customer-driven costs, the RAND report concluded:

*Customer-driven cost increases are primarily a result of (1) characteristic complexity of the vessels built and (2) other standards and features desired by the Government. Characteristic complexity is a measure of how changes to basic ship features (e.g., displacement, crew size, number of systems) make them more difficult to increase. The researchers found that increases in light ship weight (LSW) and power density (i.e., the ratio of power generation capacity to LSW) correlated most strongly with ship costs. Changes in these variables by themselves likely do not lead to increased ship costs. Instead, they indicate other changes that do tend to increase costs. Power density, for example, is related to the number of mission systems on a ship. Overall, the Navy’s desire for larger and more-complex ships has been a significant cause of ship-cost escalation. Other standards and features, such as desired improvements in survivability, habitability, working conditions both onboard and in constructing ships, and environmental regulations surrounding the construction and operation of ships, have also contributed to ship costs.* (RAND Corporation, 2006, pages 1-2)

3.2.3 RAND’s breakdown of the causes of price increases is shown in the following diagram. The elements of the chart are the components of the overall price increase, which includes inflation. If the US Consumer Price Index (CPI) is used as the indicator of general inflation, which averaged 4.7 per cent between 1965 and 2004, the annual increase in net or real terms is 3.9 per cent. See RAND Corporation, 2006, page 18 for further discussion on what deflators apply to its analysis.
In addition to quantifying sources of cost escalation, RAND Corporation asked shipbuilders for their views on why such escalation occurs:

The most common explanation shipbuilders offered related to an unstable business base and decreasing production rates. For many shipyards, the Government is the main, if not only, customer. Fluctuating ship orders, with initially forecast orders typically exceeding what is ultimately purchased, discourage shipyards from making investments that could ultimately reduce the cost of ships. An unstable business base also causes fluctuations in the demand for skilled labor that are expensive and difficult to manage and prevents contractors from leveraging through long-term contracts purchases from subcontracting suppliers. Decreasing production rates tend to increase overhead rates and make the shipbuilders and their suppliers produce at lower efficiency.

(RAND Corporation, 2006, page 2)

The RAND Corporation report recommended that ‘to reduce costs, the [US] Navy may wish to consider stable or modular designs, slower increases in complexity, or mission-focused ships, or even to change how it purchases ships (e.g., make multiyear buys). Some manufacturing investments for greater efficiency in production can help reduce costs as well’.

### 3.3 Models of Naval Shipbuilding Project Costs

#### 3.3.1

There are many ways to depict the cost (and price) structure of a project to design, construct, test, certify and deliver a warship. There are also many ways to model sustainment costs and ultimately the total cost of ownership. What follows in this section is a very basic description of some static cost and price models, which illustrate the different structures used as well as the difficulty of using high-level, static data for comparisons or value analysis.

#### 3.3.2

As mentioned in Section 1.5.1.1, this discussion paper uses the terms cost and price with different meanings. Caution is required with some of the following citations where the word is quoted from the source, where they use a different meaning. For example, the RAND Corporation often uses the term cost to mean what this paper would describe as price. There is not a right and wrong definition; it is just a matter of consistency.
In its research into the rising ‘price’ of US Navy ships, RAND found that labour accounted for 32 per cent of the ‘end cost’ of a surface combatant project, equipment 57 per cent and material 11 per cent. As with all models, the complexities are hidden in the detail – in this model, the labour category is defined only as shipyard labour:

Labor costs represent a substantial portion of the total procurement for naval ships. The following chart summarises the typical labor percentage of total cost for the four ship types. These labor percentages represent general averages provided by NAVSEA 017 for recent ship classes. Labor costs are fully burdened, including direct and overhead costs for all types of labor (e.g., engineering, support, manufacturing). These labor costs are for the shipbuilder’s contribution only. We do not have data to examine labor costs at the supplier or subcontractor level. (RAND Corporation, 2006, page 24)

The problem with this lexicon is there are considerable ‘labour’ costs in the equipment category, and the shipbuilder proportion (32 per cent) is reflective of the US environment where there are long build programs; for example, 50 destroyers, and the shipyards such as Bath Iron Works and Northrop Grumman Ship Systems outsource very little production work. Comparing this number with a labour number from another model would be dangerously misleading, unless all assumptions and limitations were understood and somehow normalised. In this model, material includes basic items used in shipbuilding such as steel, paint, electrical cable, and insulation; and equipment includes major manufactured items such as systems for navigation, weapons, command and control, and machinery such as elevators, pumps, air conditioning and electrical distribution.
3.3.5 Presented in the 2005 United Kingdom Defence Industrial Strategy, the BAE Systems model of ‘costs’ for its Type 45 Destroyer Program is shown below. The element which dramatically affects this representation is the substantial research and development cost of the new Principal Anti-Air Missile System (PAAMS), a joint French, Italian and British program.

3.3.6 Whilst there is no mandated or generally accepted model in Australia, conversations about warship project costs tend to follow the contract structure of major participants: Defence, shipbuilder, combat system integrator, and platform designer. As with the US model in Figure 3, the complexities are hidden in the detail. There is no longitudinal research data available for Australian warship programs with this or another standardised breakdown, but general commentary (not hard data) reflects a rough breakdown as shown in the following diagram.
The figure below is the budget breakdown the Air Warfare Destroyer Alliance presented during their 2007 Australian Roadshow. No dollar numbers were provided. Significant differences between this breakdown and that presented in Figure 5 – Basic Model of Warship Project Costs – are that the Alliance budget does not include Defence expenses. The Defence expenses for the Air Warfare Destroyer (AWD) Program are extensive, including the US Navy Aegis Combat System that costs more than $1,000 million.

On the surface, the models described above give very different impressions about naval shipbuilding projects. But at the core, the costs are fundamentally no different. What is not available that would provide a clearer picture is a universal model standard and associated data set, which would allow a complete, unambiguous understanding of the costs and dynamic behaviour of costs. Achieving this is probably not a realistic objective.
4.1 Naval Shipbuilding Cost Models

4.1.1 There is no simple, universally agreed model for predicting the cost of designing and building a warship. The reason for this is there are too many independent variables that affect the final cost of a project.

4.1.2 In terms of combat system costs, the degree of integration in a combat system has a substantial effect on its development, testing and certification costs. Whether the system is developmental or off the shelf is another major factor. There are various methods for estimating combat system project costs, but the key metrics are proprietary information. For example, there are methods that estimate effort using a formula that includes the number of interfaces to be developed. The methods are generally bottom-up approaches where the cost of sub-systems, hardware and software are aggregated. While there are some deterministic approaches to estimating costs of new designs, there is a strong reliance on estimates based on recent experience.

4.1.3 In terms of platform costs, the international shipbuilding industry has developed two common methods for predicting the production cost of a ship; one is weight based and the other volume based (described further in Sections 4.3 and 4.4). Machinery and material costs are calculated separately, usually using a bottom-up method of summing the cost of different items based on experience and/or quotations.

4.2 Production and Non-Production Categories

4.2.1 Before discussing the estimating models, a breakdown of effort required in a project to design and build a warship should be defined. These are general definitions and all shipyards have variations in their methods of organising and accounting for resources. The general categories are:

- **Production** – work usually defined as the recurring effort (man hours) required to construct each warship. This involves the blue collar workforce of a shipyard: welders, boilermakers, metal fabricators, shipwrights, storeman, etc. Production resources also include supervisors, production engineers, materiel managers, quality control, test and trials personnel, etc.

- **Non-Production** – work in this category includes warship hull, machinery and combat system design, production design, build strategy development, production planning, materials definition, production documentation, test and trials planning, test procedure development, certification, etc.

4.2.2 Non-production effort is the non-recurring engineering required to manufacture a warship, and it is much more than just design. In a new project, one of the substantial tasks to be completed prior to the commencement of construction is Production Engineering. Production Engineering is the discipline of working out how to build a particular warship, defining each component and how and where it is to be manufactured, defining the sequence of construction, the materials required, the manufacturing processes to be used, how hull blocks, materials and equipment will be transported, designing and documenting the quality control procedures and the test regime to be applied, and so on.
4.2.3 Good projects integrate Production Engineering into the functional design process so ships are ‘designed for construction’. This is especially important for block/modular construction so that the design is optimised for hull structure and sub-system partitioning, pre-outfitting and pre-testing. The productivity improvement from a good production engineering system is substantial – it is the driver behind the success of Japanese and Korean shipbuilding. The Spanish F-100 warship also benefited from a substantial Production Engineering effort. The costs of Production Engineering and activities affected by its output are significantly affected by the level of familiarity the designer and builder have with each other’s work (including major sub-contractors).

4.3 Weight-Based Estimate Model

4.3.1 The Weight-Based Estimate model pivots off light ship weight, which is the actual static mass of the hull and installed equipment. This is not the displacement of the ship, nor does it include variable loads such as fuel, water, crew, ammunition and other stores. Designers and builders have developed good methods for estimating these weights across a standard Ship Work Breakdown Structure (SWBS). From experience, each shipyard learns what resources it takes to produce tonnage in each category and so creates a set of cost estimating ratios.

4.3.2 These cost estimating ratios apply to a particular scenario: specific build processes and warship design characteristics. Shipyards apply factors to their production model estimates, commonly called ‘adders’, when scenarios alter. For example, building the first of class of a new design will take additional production effort to correct design deficiencies and incorporate late changes, commonly 10-15 per cent. Also, a new process in construction will change the production resources required, with new processes typically consuming more effort initially as they bed into shipyard practice. Overall, production adders of 20 per cent and more are not uncommon for the first ships in a series, of a brand new design. This is typical of the variance between core and actual productivity; see Section 9.2.2 for a further explanation. Lastly, these ratios are highly sensitive business information and are closely guarded.

4.3.3 When a new ship needs to be costed, a shipbuilder will dissect the design, create the SWBS weight breakdown, apply the cost estimating ratios and adders, and develop a production resource estimate. The accuracy is dependent upon the maturity of the design, but for ships of a similar design, it is very accurate. Estimates for a series of ships will also account for the production learning curve, described further in Section 8.5.

4.3.4 Cost estimating ratios are different for each shipyard. Two shipyards using the Weight-Based Estimate model will get different results because their productivity is different. Shipyards have different average productivity, and very different productivity in different work categories. As just one example of many, one shipyard might have better materials handling systems, another better plate line automation. Care is needed in using the results of these models.
4.4 Compensated-Gross-Tonnage Model

4.4.1 Gross tonnage is the common measure of commercial shipping, it being a measure of internal volume of a ship, not mass. The International Maritime Organisation defines gross tonnage in its *International Convention on Tonnage Measurement of Ships, 1969* in terms of ‘the moulded volume of all enclosed spaces of the ship’. Gross tonnage forms the basis for manning regulations, safety rules and registration fees.

4.4.2 Extending this volume concept into shipbuilding, Compensated-Gross-Tonnage (CGT) normalises the production work content of a ship by multiplying the Gross Tonnage by a coefficient that compensates for the relative complexity of a ship. Clearly warships are much more complex machines to build than commercial oil tankers. The CGT coefficient for a warship is determined by characteristics such as compartment size, platform shock specifications, survivability specifications, combat system equipment density, and naval construction standards.

4.4.3 An example given by First Marine International Ltd UK (FMI) (First Marine International, 2005) is a commercial bulk carrier with a gross tonnage of 113,000 and CGT coefficient of 0.31, has a CGT of about 35,000 (note there are no units of measurement for these figures). In comparison, a much smaller frigate with a gross tonnage of only 5,000, has a CGT coefficient of 9.0, which results in a CGT of 45,000. The frigate has 28 per cent more work content but only 4 per cent of the volume of a bulk carrier. More than 30 years of international research has gone into the CGT methodology, and various scales of CGT coefficient are available.

4.4.4 When a new ship needs to be costed, the CGT is calculated using details of the design and tables of CGT coefficients. The production resource estimate is calculated using the shipyard’s productivity factors (man hours per CGT), which might also be labelled cost estimating ratios, but are different from the system described in Section 4.3. As with the Weight-Based Estimate model, estimates for a series of ships will account for the production learning curve.
PART II

Business Models
5.1 Searching for Better Value Outcomes

The previous sections have examined the trend of rising prices for warships and some basic cost models for naval shipbuilding projects. The following sections now discuss some of the factors that drive costs in naval shipbuilding, hence can present opportunities to improve value in naval shipbuilding in Australia. This section examines the business models used in past and current naval shipbuilding projects, including Collins submarine, ANZAC ship, Air Warfare Destroyer and the Amphibious Ship Programs. Section 7 then examines other business models that could be applied and discusses some of their advantages and disadvantages.

5.2 Previous Projects – ANZAC

5.2.1 The acquisition strategy for the ANZAC class frigates involved an open international competition for existing designs to be built in Australia by a predominantly Australian prime contractor. A strong basis on an existing design already in operational service was mandated to reduce capability risks and reduce the need for significant non-recurring engineering effort. There were several ‘down-select’ stages until only two bidders remained. The consortia bidding for the prime contract were Australian Marine Engineering Consolidated (AMECON), led by Transfield in Williamstown, Victoria with Blohm+Voss of Germany; and Australian Warship Systems Ltd, led by Carrington Slipways in Newcastle, NSW, with Royal Schelde of the Netherlands. At this stage a partially Commonwealth-funded design definition and scoping stage was conducted to prepare the final quotations from which the Government selected the AMECON (later known as Tenix) tender based on the MEKO 200 warship design by Blohm+Voss that had been built in Germany and also several European countries.

5.2.2 The construction contract was a performance-based, fixed-price contract directly with the Australian prime contractor who then sub-contracted ship design, combat system and propulsion system design/supply and all other equipment procurement. The contract ran for 19 years and did allow for variations for certain labour and materials indices.

5.2.3 This acquisition/contracting strategy successfully delivered the eight frigates for Australia and two for New Zealand with acceptance trials performance of the ships meeting all of the major Defence requirements specified. The sizable production program (10 ships) had benefits in amortising non-recurring costs and attracting significant learning curve efficiencies. Performance risks were generally well managed with a comprehensive land-based testing regime before installation of equipment in the ships.
There were a number of lessons learnt during this lengthy acquisition program that warranted consideration during the formulation of the acquisition and contracting strategy for the subsequent AWD Program. These lessons included:

- The prime contractor conducted tender competitions for all major supplies/equipment and module construction after contract award and retained all the savings achieved compared with their tendered price.

- Defence had no contractual relationship with platform and combat system designers, losing the ability to influence their detailed design. The prime contractor could also re-interpret Navy requirements to suit their commercial situation rather than optimum solution for Navy (this particularly impacted on SMEs for some small equipment and configuration changes).

- The performance-based specification was very good for focusing on outcomes, but left the prime contractor to choose design details that were incompatible with existing Navy standards or practices or caused increased operating and/or support costs.

- Despite being heavily based on an ‘existing design’, final construction ended with significant changes to the combat system, radars, main propulsion configuration, etc that resulted in significant non-recurring design/engineering effort.

- While the prime contract included the acquisition of in-service support components, the actual delivery of in-service support was not contracted until after delivery of the first ship, resulting in lost leverage of future sustainment costs at the detailed design/equipment selection phase.

Solutions to some of these lessons were implemented in parallel with the original production contract so that all major enhancements to the ships (for example, Evolved Seasparrow Missile, Harpoon, changed helicopter and air weapons magazine) could be implemented using the ANZAC Ship Alliance created in 2001 – an unincorporated joint venture between the Commonwealth (DMO), Tenix and Saab Systems. This provided a useful learning experience that helped inform the AWD approach to an alliance business model.

In a broadly similar manner to that described for the ANZAC frigate program, although preceding it by several years, the Collins class submarine acquisition was based on an international competition conducted over several phases. Project definition studies were performed for two short-listed platform designs for each of the two short-listed combat system designs. The production contract required the establishment of an Australian prime contractor and a greenfield site for construction of the six boats (in Adelaide). The final selection was of an overseas company, Kockums AB of Sweden, which had established an Australian subsidiary during the earlier project definition studies phase.
5.3.2 Similar to the ANZAC contract, this was a performance-based, fixed-price contract with ASC
(variable only for material, labour, and exchange rates). ASC was originally owned by Kockums
Pacific Pty Ltd (30 per cent shareholding), Chicago Bridge and Iron Pty Ltd (US) (20 per cent),
Wormald Pty Ltd (Australia) (25 per cent), and the Australian Industry Development Corporation
(AIDC) (25 per cent). Government requirements were for majority Australian shareholding,
therefore AIDC and Wormald. Chicago Bridge and Iron was included for its expertise in large project
management; however, departed from the project early. Wormald were also subsequently to
leave the ASC ownership scene resulting principally in Kockums and AIDC (48.25 per cent) as
owners until the Commonwealth Government procured the Kockums shares in April 2000.

5.3.3 As the capability requirements for the Collins submarine could not be met by an existing design,
the resultant project involved extrapolation of a smaller European-based design and integration
of a ‘clean-sheet’ US combat system design developed by then Rockwell. Hence there were
considerable risks in hull and combat system design development and maturity, and production
maturity that would suggest that a fixed-price contract with a ‘start-up’ company was not
the most suitable model, even though it was successful in constraining some cost overruns.
The over-publicised design, production and combat system shortcomings are well known, but the
outstanding overall achievements for Navy capability, DSTO involvement and Australian industrial
capability are under-acknowledged, especially relative to the experience of all major European,
US and UK submarine programs. Most of the lessons learnt from ANZAC project regarding the
business model/contract structure are also relevant to the Collins project.

5.4 Current Projects – LHD

5.4.1 The contract for the construction of two Landing Helicopter Dock (LHD) amphibious ships was
awarded to Tenix Defence in 2007. The process for source selection and contract business model
were similar to the ANZAC Ship Program. The business model was a fixed-price contract with
a prime contractor and source selection was done by competition. The principal competitors for
the contract were Thales Australia and Tenix Defence, each partnered with a separate European
designer and builder; Tenix with Navantia of Spain and Thales with its parent company in France.

5.4.2 In terms of business models, the distinguishing feature of the approved project was construction
of the two hulls in the Navantia shipyard in Ferrol, Spain. The Ministerial Media Release stated:

In order to provide value for money, both tenderers – Australian companies – proposed
partial overseas builds with a high degree of Australian fitout. Much of the combat
and communications systems integration and installation – the ‘smart stuff’ – will be done
by Australian industry, which will be able to make the most of project opportunities in
the leading edge technologies – electronics, systems engineering and integration, and
design development.

The Government has ensured the Landing Helicopter Dock contract will lay the groundwork
for Australian industry to provide full in-service support for the life of the ships. This will
provide a steady and reliable source of demand on industry that, over ship life, will amount
to several times the value of the actual construction program.
Approximately one quarter of the construction of the amphibious ships will take place in Australia. The construction of the superstructure and the majority of the fitout will occur in Melbourne, with an estimated value of up to $500 million. The majority of combat system design and integration work will take place in Adelaide, worth up to $100 million for the South Australian economy. There will also be further work contracted to other states.

The amphibious ship project reflects our insistence on real-world business procedures, especially tight governance, disciplined budgeting and strong risk management.

5.5 Current Projects – Air Warfare Destroyer

5.5.1 The Air Warfare Destroyer (AWD) Program followed a very different business model and source selection process to the three programs described above. In May 2004, the Australian Government announced the AWD Program would use an alliance business model, stating the model ‘will reflect all of the key commercial principles that will govern the relationship and will rely on providing incentives to the parties to minimise costs’ (Australian Government, 2004a).

Also, as one of the first major Defence projects to follow the two pass approval process implemented following the 2003 Defence Procurement Review (Kinnaird, 2003), the AWD Program was required to examine an off-the-shelf option, the ‘Existing Design’, as well as an ‘Evolved Design’.

5.5.2 Joining with the Commonwealth, the industry participants in the alliance were originally to be:

- Platform System Designer.
- Combat System-Systems Engineer.
- Shipbuilder.

5.5.3 Announced in March 2004, the Platform System Design was a competition between three selected companies: Blohm+Voss from Germany, Gibbs & Cox Inc from USA, and Navantia from Spain. In August 2005, the Australian Government selected Gibbs & Cox as the designer for the Evolved Design. Navantia had already been chosen for the Existing Design, which was based upon the Spanish F-100 frigate platform, the Alvaro de Bazan Class.

5.5.4 The selection of the AWD Combat System-Systems Engineer was done by open competition, with bids received from BAE Systems, Raytheon Australia and Saab Systems. Raytheon Australia was announced as the successful bidder in April 2005. At that time, Government had already announced the AWD combat system would be centred on the US Navy Aegis Combat System, but the design of several sub-systems depended upon the choice of platform (existing or evolved). The selection was not a fixed-price competition, but a comparison of rates and fees, capability and attendant risks. Prices for the construction project would not be determined until second pass in 2007.
At first pass in May 2005, the Government announced the selection of ASC as the AWD Shipbuilder. Also at that time, the design of the AWD was still to be chosen following detailed evaluation of the evolved and existing platform designs, due to conclude in 2007. The selection of the AWD shipbuilder was an open competition with bids received from ASC Shipbuilding, Northrop Grumman Ship Systems USA and Tenix Defence. Given the design of the ship was yet to be chosen, the shipbuilder source selection was not a price competition, but a comparison of rates and fees, shipbuilding capability, commercial criteria and attendant risks. The Minister for Defence stated (Australian Government 2004b):

Selection of the shipbuilder will be based on a number of key criteria including:

- Commitment to the principles of a long-term risk sharing arrangement with the Commonwealth and other industry partners for the construction of the AWDs.
- A cost, overhead and pricing structure that will enable the cost effective delivery of the AWDs including the ability to build designs considering ‘whole of life’ costs.
- A sound record of past performance in building naval vessels.
- Commercial viability and financial backing.
- Access to the skilled workforce required to produce ships to the Commonwealth’s requirements.
- Willingness to provide open financial accounting data - including visibility through to the sub-contractor level – to the Commonwealth.
- Capacity to provide the Commonwealth with transparency and contractual influence over major sub-contractors.
- Capacity to access sensitive technology required for the AWD project.

At second pass in mid-2007, the Australian Government announced ‘the selection of the Navantia designed F-100 as the next generation Air Warfare Destroyer (AWD) for the Royal Australian Navy (RAN).’ In Phase 2 of the AWD Program 2005-2007, the companies had been engaged on bilateral contracts with the Commonwealth. Following second pass, ASC and Raytheon were contracted to the Commonwealth through an Alliance Based Target Incentive Agreement (ABTIA) and Navantia was contracted to the Commonwealth via a fixed-price contract. Also, the US Navy was engaged by the Commonwealth via a Foreign Military Sales (FMS) agreement, where the Lockheed Martin Corporation is a contractor to the US Navy, not the Commonwealth.
5.5.7

A diagram to explain the arrangement, commonly used by the AWD Alliance is shown below.

Figure 7 Model of AWD Program Business Structure

5.6

Current Business Models for Naval Shipbuilding in Australia

5.6.1

Overall, the most common business model for naval shipbuilding projects in Australia over the past 30 years has been a fixed-price contract with a prime contractor (Tier 1), usually the shipbuilder, selected through an open competition that included price. At the Tier 2 level in this model were the platform system designer, combat system integrator and a wide range of goods and services suppliers, all of whom were selected by the Prime Contractor, not the Commonwealth. The model is shown in Figure 8 – Traditional Prime Contractor Business Model.

Figure 8 Traditional Prime Contractor Business Model
More recently, an alliance agreement has been used for AWD with two industry participants, the shipbuilder and combat system engineering company, selected through competition that was not able to include final price. This model is shown in Figure 9 – AWD Alliance Business Model.

The market setting for these models has been fairly static, with the major naval shipbuilding companies being ASC, BAE System (formerly Tenix and Amecon), and Thales (formerly ADI). Other shipyards in Australia and New Zealand have contributed to those construction programs, including Forgacs. The construction of smaller vessels such as patrol boats, minehunters and hydrographic ships has involved smaller shipyards such as NQEA in Cairns, Austal in WA and ADI in Newcastle.

There was one notable variation in this environment, with the 2007 award of the LHD contract to Tenix. As mentioned earlier, while the LHD contract was awarded to an Australian prime contractor, the bulk of the construction will be done in Navantia’s shipyard in Spain. The decision for the overseas construction was based upon substantial cost differences.
6.1 Reasons to Review

Changing circumstances and the ongoing pursuit of improvement are reasons to review and potentially change methods. Such a review should not be considered criticism of current methods. In the past decade, the major reviews of naval shipbuilding in Australia have occurred in the development of the 2002 Naval Shipbuilding and Repair Sector Strategic Plan (Australian Government, 2002), the 2004 Carnegie Wylie review, the 2006 Senate inquiry and most recently the 2008 Mortimer Review. A summary of these reviews follows. Additionally, the 2003 Defence Procurement Review (Kinnaird 2003) recommended greater consideration of alternative forms of contracting in strategic procurement, such as, incentive contracts, alliance contracting, cost-plus incentive fee contract for development stage and fixed-price for production phase.

6.2 2002 Naval Shipbuilding and Repair Sector Strategic Plan

6.2.1 The Naval Shipbuilding and Repair Sector Strategic Plan, prepared by Defence and key industry stakeholders, was aimed at delivering more cost effective Defence capability through the sustainment of critical industry capabilities. The joint Defence and industry team conducted a detailed analysis of the sector’s industry skills supply and demand over the period 2005-2020 for three different industrial structures:

- **Model A** – a single shipbuilding entity would be operating under a sole source arrangement managed jointly with Defence as customer, including high levels of sub-contracting of modules and systems.

- **Model B** – two shipbuilding entities (prime contractors) in the sector, with major naval projects being competed or allocated between them.

- **Model C** – an industry structure that commenced with two shipbuilding entities competing for the first project, with one exiting the sector through attrition and the subsequent advantages that would accrue to the winner of the first major project.

6.2.2 The plan concluded that industry rationalisation within the naval shipbuilding and repair sector was inevitable in response to both fluctuating local demand and international trends. Hence the most effective arrangement (and lowest net cost to the nation) was for a single prime shipbuilding entity operating in a strategic alliance structure with Defence with sub-alliances/contracts for each specific project. It postulated that this outcome could arise by attrition if the loser of the first major construction contract (AWD) subsequently left the market through lack of work.
6.2.3 The Sector Strategic Plan provided a proposed policy framework to influence the industry rationalisation process, in order to mitigate the inherent risks and help shape an industrial structure designed to generate and sustain naval capability at the best possible price. It also described a ‘new way of doing business’ for the Defence-Industry relationship via alliances and contracts that should better deliver Navy’s capability requirements and achieve long-term value for money in the procurement and support of naval platforms through mechanisms such as firm contract performance targets with incentives and penalties based on international and national benchmarking, as well as maximising the sub-contracting of physical work.

6.2.4 Cognisant of the effect of fluctuating Defence demand on industry skill and key infrastructure, the Sector Strategic Plan also postulated some options for better managing demand patterns including consideration of the economic life of naval ships and submarines. An analysis of the surface combatant force identified net benefits from shortening their lives to about 20 years and not conducting the very expensive mid-life upgrades/modernisations (such as the recently conducted FFG upgrade). As will be discussed in Section 7.3, it appears the Ministry of Defence in the United Kingdom have reached the same conclusion for surface combatants.

6.2.5 Being the first of the industry sector plans, the Government allowed considerable time for discussion and analysis of the plan, especially the controversial industry interventionist model, as it overlapped the conduct of a thorough Defence Capability Review during 2003. During this period, the Government was also considering the mechanism for the sale of ASC which might have been used to facilitate part of the rationalisation. With particular concern to avoid monopoly arrangements, the Government did not endorse the plan, and subsequently selected Carnegie, Wylie & Company to provide further commercial advice regarding the naval sector in January 2004.

6.3 2004 Carnegie, Wylie & Company Review

6.3.1 The Australian Government engaged Carnegie, Wylie & Company in January 2004 to review several matters relating to naval shipbuilding. The Ministerial Media Release described the scope as follows:

Mr Wylie will provide the Government with commercial advice on:

- Implementing the naval shipbuilding program contained in last November’s Defence Capability Review (DCR), which includes the acquisition of three Air Warfare Destroyers; two large amphibious vessels; one sea lift ship and one operating oiler to be refitted in Australia.
- Progressing the sale of the ASC, which provides through life support and maintenance of the Commonwealth’s Collins Class submarine fleet.
- Other matters relating to the Naval Shipbuilding and Repair Sector Strategic Plan that was developed by Defence in consultation with industry and released in August 2002.
In May 2004, the Government announced:

The key decisions, which flow from the Government’s consideration of commercial advice provided by independent expert Mr John Wylie of Carnegie, Wylie & Company, are as follows:

- Given the significant increase in naval shipbuilding and repair sector expenditure resulting from the Defence Capability Review, a competitive model is the preferred approach for contracting in the NSR sector with intervention by the Government only in exceptional circumstances.

- The $4.5-$6 billion Air Warfare Destroyers (AWD) build contract will be brought forward and let before the $1.5-$2 billion amphibious vessels contract while maintaining the in-service dates for these projects set out in the Defence Capability Plan.

- It is planned that tenders for the AWD build will be issued later this year with a preferred tenderer to be identified by early 2005. It is planned that tenders for the amphibious vessels build will be issued in early 2005 with a preferred tenderer to be identified by late 2005.

- Tenderers for the AWD contract will be asked to bid on the basis of an alliance relationship with the Commonwealth. An alliance contract will reflect all of the key commercial principles that will govern the relationship and will rely on providing incentives to the parties to minimise costs. Mr Wylie will assist Defence in the development of the detailed terms of the alliance relationship.

- The sale of the Australian Submarine Corporation (ASC) will be deferred until after the AWD and amphibious vessels are in contract to allow shipbuilding industry – including the ASC – to focus on tendering for these projects. As a result, it is unlikely that ASC will be sold until 2006.

- While ASC will be permitted to tender for major naval shipbuilding contracts, it must do so on an arm’s-length basis from Government. To ensure this occurs, ASC will be established as a Government Business Enterprise under the Commonwealth Authorities and Companies Act, which will require the company to operate efficiently, earn at least a commercial rate of return and observe a more standardised and transparent reporting framework. Strict procedures governing the relationship between ASC, Defence and Finance will also be put in place.

In terms of business models for naval shipbuilding in Australia, the review resulted in ASC becoming a Government Business Enterprise and the adoption of an alliance model for the AWD Program.
6.4 2006 Senate Inquiry

6.4.1 The scope of the 2006 inquiry by the Senate Standing Committee on Foreign Affairs, Defence and Trade was defined as:

The terms of reference focus on the future of Australia’s naval shipbuilding and repair industry, its capacity, its economic viability, and the broader economic implications stemming from the construction of large naval vessels in Australia. The terms of reference required the committee to inquire into and report upon the scope and opportunity for naval shipbuilding in Australia and in particular:

a) the capacity of the Australian industrial base to construct large naval vessels over the long term and on a sustainable basis;

b) the comparative economic productivity of the Australian shipbuilding industrial base and associated activity with other shipbuilding nations;

c) the comparative economic costs of maintaining, repairing and refitting large naval vessels throughout their useful lives when constructed in Australia vice overseas;

d) the broader economic development and associated benefits accrued from undertaking the construction of large naval vessels.

6.4.2 The Committee’s report was released in December 2006, describing the main finding as:

The committee has taken a measured and balanced approach to presenting and analysing the evidence. The lack of data in particular caused the committee to be cautious in reaching its main finding. The evidence, however, was clear cut – Australia’s naval shipbuilding base is well-established, and in recent years has become more efficient, motivated and highly skilled. It has produced a number of outstanding world-class vessels that showcase the capability of Australia’s naval industrial base. In assessing the four major components of Australia’s naval industrial base, the committee found:

- Australian prime contractors have an improved track record.
- SMEs and international subsidiaries form a vibrant, innovative and competitive network of suppliers.
- Past and current investment in heavy engineering infrastructure outside the traditional shipbuilding yards places the industry on a sound but flexible footing to meet future demand.
- Initiatives by both the public and private sector are tackling the problem of skills shortages to ensure that Australia has the knowledge and skills to support the industry.

6.4.3 The Committee made eight recommendations covering the Government’s commitment to naval shipbuilding in Australia, cost modelling and benchmarking, Australian industry involvement policy, further analysis of ways to improve industry performance, and improvements to the Defence Capability Plan. There were no specific recommendations regarding business models used for naval shipbuilding in Australia.
6.5 Mortimer Review

6.5.1 In May 2008, the Australian Government announced that ‘a formal evaluation of the effectiveness of ongoing reforms to the Defence Materiel Organisation (DMO)’, which would be conducted by Mr David Mortimer AO. In its May 2009 response, the Australian Government agreed to most of the review’s recommendations (42 in full, three partially and one not agreed).

6.5.2 As a result of the review, the Australian Government said ‘the Defence Materiel Organisation will embark on a radical change program to become more business-like in supporting its customer, Defence’. The four key principles of the ongoing reform were stated as:

- The Defence Organisation must become more accountable and transparent in managing the billions of dollars invested in building military capabilities.
- The Defence Materiel Organisation must strengthen its capacity to provide independent advice to Government.
- The Defence Materiel Organisation needs a strong business-like culture to deliver projects on-time, on-budget and to Defence’s requirements.
- The strong relationship between Defence and the Defence Materiel Organisation must be further strengthened. The key priority is meeting Defence’s military capability needs and by extension keeping Australia secure.

6.5.3 In addition to the general effect these reforms will have on naval shipbuilding in Australia, some of the specific recommendations/actions have more direct implications. In particular, Defence will plan for more Off-The-Shelf (OTS) procurement: ‘As has been the case since the Kinnaird Review (Kinnaird, 2003), OTS options will be considered as an option for all procurements. Defence will provide Government with clear information on the costs and benefits of OTS options for all procurements’.
7.1 **Today’s Changing Environment**

7.1.1 As stated earlier, changing circumstances and the ongoing pursuit of improvement are always reasons to review current practices. The retention of ASC in government ownership, the global financial crisis and the naval shipbuilding long-term plan announced in the 2009 Defence White Paper are reasons to again review naval shipbuilding in Australia.

7.1.2 In February 2009, the Australian Government announced the planned sale of ASC Pty Ltd would not proceed, and the company would remain in government ownership. The Media Release stated:

> Lindsay Tanner, Minister for Finance and Deregulation and Joel Fitzgibbon, Minister for Defence emphasised that the current uncertainty in global financial markets presented significant risks to a successful sale of the company. In addition, a sale in the short term could complicate the operations of the company given ASC is currently building the Royal Australian Navy’s Air Warfare Destroyers and likely to be considered in any future submarine build program.

7.1.3 This decision means that for future naval shipbuilding contracts, there will be one government shipyard to be considered in source selection. If only for reasons of perception, this will require careful treatment in future source selections. The Government shipyard may also require the use of different business models to achieve the same outcomes that commercial pressures force in private companies.

7.1.4 Another recent, key strategic issue for naval shipbuilding in Australia is the move by State Governments to build and own shipyard-like facilities. The Governments of South Australia and Western Australia have both built large common user facilities. Both facilities include wharf and land-level facilities. The South Australian facility has a ship lift; the Western Australian facility has a floating dock. Not only does this provide more shipyard facilities, but also their common user status allows new companies into the market without the need to invest large sums of time and money in infrastructure.

7.2 **Levels of Change – Strategic and Tactical**

7.2.1 Without a clear border between them, there are two levels at which to consider improvements in the approach to naval shipbuilding in Australia. At the strategic or national level, there should be ongoing consideration about the retention and advancement of high priority skills for the effective support of naval capability. There should also be consideration about whether there will be an effective open market at the prime contractor level in Australia for complex shipbuilding programs given future workload and the infrastructure requirements for naval ship consolidation (not block and module manufacturing), and whether there may be lower cost arrangements.
7.2.2 As an example of another nation’s strategic consideration of naval shipbuilding, the United Kingdom recently transitioned to a single naval shipbuilding prime contractor operating under a strategic, performance-based agreement with the Ministry of Defence. The move was largely driven by declining industry workloads after their aircraft carrier project ends. The change is described further in Section 7.3 below.

7.2.3 At the tactical or project level, there should be consideration of different methods of contracting such as the use of shared outcome versus fixed-price contracts. This was the adjustment made for the AWD Program, which moved away from the fixed-price type used for the ANZAC and Collins Programs to an alliance agreement.

7.3 Strategic Change – the United Kingdom Approach

7.3.1 In 2005, the British Government produced a Defence White Paper entitled the Defence Industrial Strategy (UKDIS). The aim was to provide greater transparency of its future defence requirements and, ‘for the first time, setting out those industrial capabilities we need in the UK to ensure that we can continue to operate our equipment in the way we choose’. The remark that this was ‘the first time’ the Ministry of Defence in the United Kingdom (MODUK) had defined key industrial capabilities is particularly important. The Defence Industrial Strategy provided a strategic view of defence capability requirements in acquisition and sustainment, and by sector. The strategy specified which industrial capabilities needed to be retained in the UK for Defence reasons. Ten sectors were defined: systems engineering, maritime, armoured fighting vehicles, fixed-wing including unmanned aerial vehicles, helicopters, general munitions, complex weapons, C4ISTAR, CBRN force protection and counter terrorism.

7.3.2 The MODUK demand for warships is not grossly different from Australia’s, notable differences being large aircraft carriers and nuclear submarines. As stated in Section 2.2.3, Australia will acquire 48 naval vessels over the next 20 years, having acquired 40 in the previous 20 years. The UK plan is to acquire about 50 naval vessels over 20 years (RAND Corporation, 2005a, page 1). For the maritime sector, the UKDIS defined the required skills:

*To sustain this capability: it is a high priority for the UK to retain the suite of capabilities required to design complex ships and submarines, from concept to point of build; and the complementary skills to manage the build, integration, assurance, test, acceptance, support and upgrade of maritime platforms through-life.*

(Ministry of Defence, 2005, page 7)

7.3.3 The UKDIS went on to acknowledge that the British Government had previously specified that warships should be built in the UK, but for strategy going forward the situation was put succinctly: ‘at issue is the capacity required’. The fundamental issues were affordability and productivity. The forecast was that from about 2016 the steady-state demand for naval shipbuilding would be significantly lower than the peak created by the Type 45 Destroyer and Aircraft Carrier (CVF) Programs.
In response to this predicament, the UKDIS set down some clear, strong directions for the UK naval shipbuilding industry, with statements such as:

*The industry, which is currently fragmented, needs to consolidate and refocus around a core workload which sustains key capabilities and represents a viable business.*

*We will immediately start negotiations with the key submarine companies with the aim of achieving a programme-level partnering agreement with a single industrial entity for the full life cycle of the submarine flotilla, addressing key affordability issues.*

*For Surface Ship Design and Build, within the next six months, we aim to have reached a common understanding of the core load required to sustain the high-end design, systems engineering and combat systems integration skills that we have identified as being important. We expect industry to begin restructuring itself around the emerging analysis to improve its performance, and shall build on the momentum generated by the industrial arrangements being put together on the CVF programme to drive restructuring to meet both the CVF peak and the reduced post-CVF demand.*

(Ministry of Defence, 2005, page 77)

One of the primary inputs to the development of this maritime industrial strategy was research done by the RAND Corporation. Commissioned by the UK Defence Procurement Agency in 2003, RAND examined three fundamental questions: can the existing shipbuilding industrial base meet future demands; do problems exist with the numbers and types of facilities or the numbers and skills of the workforce; and if problems exist or can be anticipated, what can be done to alleviate them? Following very extensive analysis, RAND *(RAND Corporation, 2005a)* found:

- The naval shipbuilding workload would rise in the period 2007-2013, followed by a significant decline from about 2016. In terms of labour demand, the direct headcount of the workforce was forecast to rise from 10,000 in 2004 to a peak of 16,000 in 2008, then drop to 4,000 in 2024.

- After ‘decades of consolidations and bankruptcies’, only three major firms were involved in naval shipbuilding: BAE Systems, Swan Hunter and VT Shipbuilding.

- While there are other labour sources from which shipyards can draw workers, it will be difficult for the shipyards to grow to meet demand.

The report made eight recommendations for action in the short term, and the following six for the long term:

- Make long-term industrial planning part of the acquisition process.

- Define an appropriate role for the offshore industry.

- Carefully consider the implications of foreign procurement of complete ships.

- Encourage long-term investment through multi-ship contracts.
7.3.7
The 2005 RAND report (RAND Corporation, 2005b) is characterised as a macro analysis of the UK naval shipbuilding industry. In 2006, the MODUK commissioned follow-up research with RAND to investigate the specific technical skills the UK’s maritime industry would need to sustain to preserve the country’s ability to design, build and support complex warships and submarines. This micro analysis found that ‘the supply-demand relationship is highly complex and that some technical skills are extremely sensitive to demand’. The report concluded:

> To preserve its ability to design, build, and support complex warships and submarines, the UK Ministry of Defence (MOD) will need to preserve and sustain several key technical skills in the maritime domain. In particular, it needs to nurture detailed designers and professional engineers involved in various stages of surface ship and submarine acquisition and support. Although MOD has taken into account its need for these skills, its significant future maritime programme likely will have to be modified or augmented to sustain these technical skills in the long term. (RAND Corporation, 2008)

7.3.8
The work by the MODUK is landmark. Their work leading up to the maritime industrial strategy in 2005, and since, has been thorough in its analysis and deliberate in its actions. Today, the MODUK have established one supplier for the acquisition of complex warships, and one supplier for sustainment.

7.3.9
Formed on 1 July 2008, BVT Surface Fleet, a joint venture between BAE Systems and VT Group, is the designer and builder of complex warships for the Royal Navy. At the beginning, MODUK signed a Terms of Business Agreement which pledges that the vast majority of its naval vessel orders will be placed with the new company for 15 years. In January 2009, as many expected, VT Group announced it planned to sell its 45 per cent stake in the joint venture to BAE Systems for about £380 million in accordance with a ‘put option’ in the founding agreement. The sale has MODUK’s approval.

7.3.10
The UK business model for naval shipbuilding for complex warships is now a directed, regulated source. The value proposition is a long-term partnering relationship, underpinned by strong customer-supplier engagement. The outcome was publicly characterised as ‘the fight coming to an end’ as the companies involved, Babcock International, BAE Systems and VT Group, implemented agreements that would see work shared and savings split with the MODUK. At the time, the CEO of the VT Group was quoted as saying “we don’t want to get into a dogfight with BAE over who would be the survivor ... that’s what you’d be talking about at some stage”. In return for industry cooperation, the MODUK guaranteed work for 15 years, long enough for the companies to make the investment in equipment and training needed to keep the fleet afloat.
The implementation of this arrangement had and has its challenges, and the economics of the arrangement is discussed further in Section 7.3.13. The move away from a competitive market was a decisive step, which required the approval of the Ministry of Defence, Treasury and other government agencies. The underlying rationale for accepting this departure, as stated by RAND in their 2005 report, was:

*Competition may not always yield better prices or result in a balanced allocation of work under conditions in which there are high resource demands. In such an environment, it is possible that there will be fewer potential bidders on subsequent programmes, that bidders will take on more work than is optimal, or that shipyards will be less inclined to cooperate for fear of losing a competitive advantage.* \(\text{(RAND Corporation, 2005a, summary xxxiii)}\)

To implement the directed business model, MODUK used the data from its worldwide reviews of shipbuilding to set metrics and targets for its new operations. MODUK’s 15-year plan has incentive and capability payments for the industry to reach world standards. At the end of this period, MODUK has said it will pay the costs for only one shipyard, leaving it to industry to determine if more than one location is viable.

Specific details of the regulated contracting arrangements are naturally classified, but they involve open-book accounting and very specific performance targets that cover the entire operation of the acquisition activity. For a shipyard, that would likely be productivity measures such as man hours per tonne (see Section 9 for further detail). Other targets include ship availability in terms of sea-days per year. If they meet annual targets, companies receive capability payments to invest in training and technology to drive further their performance improvement. There are long-term goals to reduce naval shipbuilding costs per year by more than £1 billion.

One of the other UK reform principles was that warships should have a shorter life. The concept is to keep warships for only 15 or 20 years of service, and then replace them with a new ship, with a new combat system designed to meet the new generation of threats. The warships would still have a useful period of service life remaining and would be sold to foreign navies. The strategy is aimed at avoiding the substantial costs of major ‘mid-life’ upgrades. The difficulty with this approach for Australia is the combat systems are not indigenous and foreign government approval would be required for any sale. Gaining that approval is unlikely for advanced US technology such as the Aegis Combat System.

**Tactical Change – Alternative Business Models**

In other complex contracting environments such as the oil, gas, mining and construction industries, different acquisition models such as Front-End Engineering Design (FEED), Design and Construct; Engineer, Procure, and Construction Management (EPCM); Alliances; and Public Private Partnerships have been adopted in an attempt to better equate risk and reward for all parties without restricting the ability of the customer to be in control of the outcomes.
These models provide mechanisms which, in differing circumstances, can more effectively match the different risk profiles in different projects. Many of these models promote an improved form of collaboration, especially in the early stages of capability definition and option identification. This early collaboration is not at the exclusion of competition in the later stages of a project, such as construction. Whatever the model, it is not a guarantee of a successful project.

There is room to improve performance-based contracts linked to operational availability and this would have an impact on logistic support arrangements. For example, once a capability requirement is determined and defined by Defence, a better value solution may be achieved by tendering a combination of the capability performance and through life cost/availability on a ‘power by the hour’ or sea-days available basis. This would leave the risk of design, construction and operational serviceability with the contractor and allow Defence to concentrate on crewing, training and operational performance. Defence has used this contracting model for the Hawk training aircraft and in 2003 for the Armidale Class Patrol Boats. But there is a problem with this approach if the customer wants to put conditions on the actions of the supplier. For example, if the Government requires the capability/work to be done in Australia, that constrains the contractor, which will likely increase costs and/or reduce savings.

**Alternative Business Models – EPCM**

Firstly a word of caution. Labels like Engineer, Procure, and Construction Management (EPCM) project model do not have a codified meaning – quite reasonably, their meaning varies in different conversations. In common usage they generally accord to the same concept, but there can be confusing differences.

In a discussion on value in naval shipbuilding in Australia, the EPCM project model is noteworthy because it introduces some significant changes to the architecture of a major project in comparison to the prime contractor model often used for defence projects. In other industry terms, the defence prime contract model is called, amongst other labels, a Design and Construct contract or an Engineer, Procure and Construct (EPC) contract. In an EPC project model, the contractor manages and executes the project, selecting and engaging sub-contractors as they require. Cost control and risk are largely carried by the prime contractor. In an EPCM contract, the contractor does not execute the construction, but provides the professional services to engineer the solution and manage its construction. In this model, the contractor works more in partnership with the customer and cost control and risk is shared.

In the construction and other industries, both EPC and EPCM models are used. They suit different circumstances; the EPC contract is a more hands-off approach that suits more defined projects. The EPCM model is more collaborative that suits less well-defined projects, but it does require more skills within the customer organisation. The EPCM model is discussed further in Section 13.
7.6 Naval Shipbuilding Business Model Summary

7.6.1 In an industry as large, enduring, complex and nationally important as naval shipbuilding, there are always risks to future success and opportunities for improvement that compel review and sometimes change. This section examined the national reforms the United Kingdom has underway. While their circumstances are not entirely the same as Australia’s circumstances, the changes are worth studying. It is of interest that Australia and UK were starting to come to grips with the costs of owning a modern naval shipbuilding industry in a similar time scale.

7.6.2 This section also touched on different contracting methods used to drive improved performance in other industry sectors. The choice of contract method depends primarily on the risk profile of the project, and a variety have been used on naval shipbuilding programs in Australia over the past 20 years. The choice of an alliance for the AWD Program has been seen by some as controversial, which is probably due more to the model being new to Defence, rather than being unsuitable to that project. A reverse view would be taken in other industries where Alliances are the norm, such as the oil and gas sector.

7.6.3 The topic of business models, or more broadly project models, is covered in more detail in Section 12 and beyond. This follows some discussion in Sections 9 and 10, which cover some engineering aspects to a naval shipbuilding projects that can affect costs, hence value.
PART III

Warship Construction
8.1 What it Takes to Build a Destroyer

To provide some context for the following discussion, here is a list of some of the materials required to construct an Air Warfare Destroyer:

- Piping 50,700 metres
- Electrical cable 427,300 metres
- Steel 4,770 tonnes
- Valves 4,700
- Flanges 61,500
- Rope 6,200 metres
- Paint 137,800 litres
- Fasteners 1,570,400

8.2 Production and Non-Production Costs

8.2.1 As described in Section 3.3, there are many ways to model the cost structure of a warship project. One of the useful, basic models uses the division of production and non-production effort. This is sometimes referred to as white collar and blue collar, but that language is highly subjective and varies widely according to the management practices of countries and individual shipyards. For example, some shipyards account for white collar supervisors in blue collar production categories. Other shipyards create categories such as ‘light blue’. This division is sometimes referred to as non-recurring and recurring effort, but that is not strictly the same because there is recurring white collar and non-production effort in shipbuilding (depending upon definitions).

8.2.2 A general rule in warship projects has been the non-recurring engineering cost equates to the production cost of one ship. For example, in a four-ship program, 20 per cent of the budget would be for non-recurring costs, with an average of 20 per cent for the production of each ship. The dollar value for this non-recurring work is roughly in the order of $1-2 billion, more for highly developmental programs. While there is no specific research that defines a change from this general rule, the work by RAND and general data available on the AWD Program suggests the proportionate cost of non-recurring engineering is increasing. As stated, there no definitive research to finalise this conclusion, and it would be a worthwhile aspect to an ongoing analysis into improving value in naval shipbuilding in Australia.

8.2.3 RAND identified that economy-driven and customer-driven factors each accounted for about half the sources of ship cost escalation (see Figure 2). Within the customer-driven factors standards and Requirements, and Complexity account for 2.1 per cent and two per cent respectively of the overall trend of a 9.1 per cent per annum increase. These factors are primary drivers of the level of non-recurring engineering in a project, rather than drivers of production costs. One deduction is that within the increasing price of warships, there is a much larger percentage increase in non-recurring engineering costs as compared to production costs and, consequently, the proportion of non-recurring engineering costs within a project is increasing.
8.2.4 Identifying the actual production cost of a destroyer like the AWD is difficult because refined data is not available. Production cost will always be less than unit cost or average price because those numbers must include a share of non-production/non-recurring costs. In testimony to the Senate Armed Services Committee in 2005, the Chief of Naval Operations stated the average price (not production cost) of a DDG–51 Arleigh Burke destroyer was $US1.124 billion in 2005 (@AUS$0.76 = $1.470 billion). Noting this was a 61-ship build program, this average price will be closer to production cost, much more so than for the more common three to six build destroyer programs. There is no data available publicly on the cost of the Spanish F-100 frigates.

8.2.5 Department of Defence Portfolio Additional Estimate Statements for 2007-08 define the Approved Project Expenditure for the SEA 4000 Air Warfare Destroyer Program as $7,025 million. If the average production cost is assumed to be $1,500 million per ship, then the non-production/non-recurring engineering costs are about $2,500 million, 1.67 times the production cost of each ship. Returning to the data at Figure 1 – Destroyer and Frigate Prices (Department of Defence) – the AWD average price ($2,340 million) would plot above the trend line, which suggests higher non-recurring costs (assuming price in this graph is total budget divided by number of warships).

8.2.6 The precise mathematical ratio of non-recurring to production cost is not critical in this discussion, what is important to recognise is modern warships are increasingly complex, and accept this trend drives the cost of non-production/non-recurring activities up in proportion to production costs. Intuitively, it makes sense that warships take more effort to design as systems become more complex, especially as the level of system integration increases. More complex warships also require more project control, testing and certification, which supports the hypothesis of increasing non-recurring/non-production costs. What should also be acknowledged is that Australia's demand for warships is low in number and this quite fairly attracts a premium in cost to build them in Australia.

8.3 Project Cost Drivers – Warship Design

8.3.1 There are two aspects of warship design that impact project cost; design stability and design for production. The stability of a design, conversely the number of in-process modifications, is a very well recognised cost-driver in warship projects. While Australia has not undertaken a clean-sheet design of a warship, it has experience with modified designs. Both ANZAC and COLLINS were modified versions of European warships. The RAN DDGs and FFGs were existing USN designs when delivered to the RAN (and mostly constructed in the US), but both classes underwent major mid-life modernisation programs to largely Australian designs. Design stability is a key factor regardless of the origin of the design.

8.3.2 The AWD Program was particularly useful in benchmarking the relative cost of existing and modified designs as both those options were developed for government consideration at second pass in 2007. The AWD Program showed that it takes very little modification of an existing design for the costs to escalate to a level not dissimilar to a new design. The inter-relationship between elements of a warship design are extensive and intricately balanced. A small change in one area can very quickly cascade into a long series of extensive modifications to other systems and elements of the design, including hull size.
8.3.3 This sensitive nature of design stability as a cost driver is also shown in RAND’s findings:

In contrast to this 9.1 per cent annual growth rate for surface combatants, the recent growth rate for the DDG-51 program shows a much more modest rate of increase. Between 1990 and 2004, the price for a DDG-51 grew, on average, by only 3.4 per cent per year – a value slightly higher than the CPI over this time. Such a modest growth rate results from the fact that a relatively stable design was being produced (i.e., with no significant changes in complexity or capabilities). This observation corroborates our earlier observation that most of the growth beyond inflation is due to changes in the customer-driven factors. (RAND Corporation, 2006, page xvii)

8.3.4 One point of caution with the above quote. The figure of 9.1 per cent is unadjusted for inflation. RAND cites the real annual growth rate of guided missile destroyers from 1950 to 2000 as 2.1 per cent. (RAND Corporation, 2006, page 2)

8.3.5 The development of a warship’s design to aid production has a substantial impact on construction costs. The reputation of many countries and shipyards for efficiency is due not so much to their superior heavy engineering processes, but to the development of designs that are easy to construct. Korea and Japan are at the forefront of production engineering. The Spanish F-100 warship, the basis of the Australian Air Warfare Destroyer, is an example of a ship that has been designed for production. Some of the features of such designs are straighter cable and pipe routings, commonality of fittings, and wider access routes. See the description of Production Engineering at Section 4.2.2 for more explanation.

8.4 Project Cost Drivers – Build Duration and Keel Intervals

8.4.1 The time taken to build a warship is an important variable in the cost of naval shipbuilding. The primary factors are overhead burden, process efficiency and risk management. If the build duration is too long, the overhead of running the project becomes a disproportionate cost burden. There are additional costs with supplier management, supply chain overheads, in-build maintenance and obsolescence management. Possibly counter-intuitive, but too short a build period can also drive up costs. This is caused by inefficient work practices and additional project coordination effort. A higher rate of work requires more people and their efficiency is dramatically affected by the limited space in a warship. Idle time and shift penalties are some of the factors which drive up those costs when work is compressed.

8.4.2 The USN DDG-51 program has extensive experience with different build durations. A DDG-51 has been built in as few as 42 months or as long as over 70 months. While the precise data is sensitive, the general result is a build duration of about 55-60 months is considered optimum for this warship in the US shipyards involved. As a comparison, the build duration for the first AWD is 67 months, with ships two and three scheduled for 68 months. The first Korean KDX-III was built in 54 months, although originally scheduled for 48 months. The first four Spanish F-100 warships were built in 54-60 months. A word of caution: milestones like ‘start fabrication’ and ‘delivery’
are interpreted in many different ways and often timed for publicity purposes, so should not be treated as precise measurements, but general comparisons are valid. The learning curve effect on labour productivity for the earlier ships is important here – see Section 8.5.3.

8.4.3 Cadence is also an important cost variable in naval shipbuilding, that is, the interval between successive keel laying milestones or successive delivery milestones, not the duration of construction for each platform. Older shipbuilding methods involved the construction of a ship in a dry dock from the keel up, sometimes called ‘straight stick’ construction. The keel-to-keel interval was constrained by the fact one ship had to be launched from the dry-dock before the next ship could commence. With modern block fabrication methods, shiplifts and land-level facilities, much more construction happens in parallel. Controlling the keel interval variable is important to project cost. If the interval is too long, the overhead of running the project becomes a cost burden. If the interval is too short, proportionally more project coordination effort is required to manage ships in parallel, lessons learnt do not flow as effectively and all this is cost inefficiency.

8.4.4 Achieving a balance in duration and keel interval leads to a more stable pattern of work and hence a more stable work force; blue and white collar. This is desirable in a situation where skilled labour is limited, because it allows the existing workforce to correct problems and schedule slip, rather than initiate urgent demands for additional workers.

8.4.5 Risk is another cost affected by build duration and keel interval. Avoiding short-build durations and rapid-keel intervals provides more flexibility in project control, reduces risk and hence reduces risk costs. For example, a well balanced build duration might only occasionally require two work shifts each day, so re-work and lost time can be made up with extra shifts rather than trying to force extra work into an otherwise busy day. Similarly, if the keel interval is reasonably spaced, time can be made up if the work program slips. A longer interval also allows more time for re-work, modification and upgrade between platforms. Should strategic circumstances change, build duration and keel intervals can be shortened.

8.5 Project Cost Drivers – Production Learning Curves

8.5.1 The mass production principle that building more units leads to lower per unit cost is universally recognised. While warships are not mass production items like cars, the same principle does apply and shipbuilding projects do achieve a reduction in production effort between ships in a series.

8.5.2 Shipyards all measure the decreasing number of production man hours required to build a series of ships. Obviously substantial modification to ship design or shipyard processes interrupts the steady state, and typically increases production man hours, at least initially. Measurements show the learning curve is not linear: the gain between the first and second ship of a series is not repeated for each of the following ships. The learning curve gain is greater at the beginning, but results do show improvements even in relatively long build programs like DDG-51, which will exceed 50 warships.
8.5.3 The learning curve is usually quoted as a percentage reduction in production man hours, as the production volume doubles. For example, for a 90 per cent learning curve, there would be a 10 per cent reduction in the man hours consumed between the first and second ship, but it takes until the fourth ship (double) to reduce a further 10 per cent, and then to the eighth ship to achieve the next 10 per cent. The trend is shown in Figure 10.

8.5.4 Learning curves of 90-94 per cent are typical in naval shipbuilding. However, this is not a measure of shipyard productivity; that is a function of the gross number of man-hours required to build a ship, not the saving between ships in a series.

8.5.5 There is also a sting in the tail with what is generally known as ‘last ship syndrome’. Not always, but frequently, productivity drops when a shipyard gets to the last ship in a series for a whole range of reasons: attention turns to the next project or campaigning for a new contract, key staff are moved on, staff leave the company concerned about future employment prospects, redundancies can occur, and so on. These things occur within the shipbuilding company and also in the Tier 2 and Tier 3 supplier community. The drop off in productivity, the increase in last ship costs, can be substantial. This syndrome is a very good reason to avoid a run of short programs.
9.1 What is Shipyard Productivity?

9.1.1 The productivity of a shipyard is a measure of the effort the yard requires to produce a specific product, the usual measurement being man hours per tonne (sometimes called Compensated Gross Tonne). Productivity varies considerably between shipyards, both within a country as well as internationally. While productivity is a major cost driver in warship construction, it is not a variable strongly affected by the choice of warship to build. Long-term shipyard productivity can be negatively affected by the timing of capability decisions, but improving productivity is more dependent upon industry factors and shipyard management.

9.1.2 Shipyard productivity is a complex matter that is an entire subject in its own right. Productivity is dependent upon factors both intrinsic and extrinsic to a shipyard, and many are historical. Intrinsic factors include quality management, as well as numbers, skills and experience across all workforce categories, industrial relations, capital investment program, automation, geographic and physical constraints, and level of production engineering. Extrinsic factors that affect shipyard productivity include commencing with an immature design, design stability, delays in supplies, national industry structure, national workforce supply and demand, stability of orders, and competition.

9.1.3 The key determinant of shipyard productivity is the quality of management. The leadership of a shipyard is accountable for creating the environment productivity is understood and improvement programs are funded and pursued within a high-morale workforce.

9.2 Variance in Shipyard Productivity

9.2.1 The difference in productivity between shipyards can be dramatic. An old example is the Kongo Class warship, essentially a copy of a DDG-51, built in Japan using half the number of production man hours compared to US shipyards at that time. As will be discussed below, much has changed, but the differences in shipyard productivity are substantial and ‘not just savings in the margin’.

9.2.2 An important distinction often made in discussion about shipyard productivity is the difference between core and actual productivity. The common definition is core productivity is the best productivity a shipyard achieves with its current facilities and workforce, a stable design and stable manufacturing process. As the term suggests, actual productivity is what is being achieved on a program and there are a myriad of factors why a shipyard would not achieve core productivity on a project. For example, new design, new facilities, new processes, new management, new workforce, new industry structure, etc. The key point is not to assume that a high performing shipyard will achieve the same level of productivity on all tasks – they frequently do not.
9.3 Global Productivity Studies

9.3.1 The most extensive research done into naval shipbuilding productivity is a fairly recent study completed for the US Department of Defense. The major report, *Global Shipbuilding Industrial Base Benchmarking Study – Part 1: Major Shipyards* was completed in 2005. This report was based on the benchmarking assessments and recommendations of an independent company, First Marine International (FMI) UK, whose work in this field covered 30 years of productivity analysis of more than 150 shipyards around the world. The FMI work for the US Department of Defense is ongoing.

9.3.2 This was a substantial body of work driven by the US Navy, which, along with the US Congress, was concerned at the rising costs of warships. The report and subsequent testimonies to US Congress are publicly available.

9.4 Compensated Gross Tonnage

9.4.1 First Marine International’s (FMI) system of assessing shipyard productivity revolves around the measure of Compensated Gross Tonne (CGT). The CGT methodology was described in Section 4.4. In assessing a shipyard’s productivity, FMI assessed 50 elements across seven groups: steelwork production; outfit manufacture and storage; pre-erection activities; ship construction and outfitting; yard layout and environment; design, engineering and production engineering; and organisation and operating systems. The assessment is sophisticated and thorough. The end result of the FMI process is shipyards are given an Overall Best Practice Rating on a scale of 0.0-5.0.

9.5 Global Benchmarks

9.5.1 The FMI report of 2005 found the average productivity of the assessed US shipyards building warships had improved from 3.1 in 2000 to 3.6 in 2005. This compares with an international average in 2005 of 3.8. In simple terms, while the productivity of US shipyards has improved, it is not world average or world’s best practice. There is variance across each of the shipyards assessed as well as across the seven assessment groups. Information about specific yards is confidential.

9.5.2 FMI has not done a similar semi-public assessment of Australian shipyards involved in the construction of warships. FMI did a private review of BAE Systems’ shipyard at Williamstown, Victoria (formerly Tenix) in 2005-2006, but the scope is unknown and the company retains the commercially sensitive results. Some initial work by the Defence Materiel Organisation suggests there is significant variation in the record of different Australian shipyards. The performance of some Australian shipyards on specific programs does compare favourably with international benchmarks, whilst others are notably less efficient.
Future Performance of Australian Shipyards

Shipyard productivity has a direct impact on costs, but it needs to be recognised the hull construction component (labour and material, but not equipment) of a warship project is around 20-30 per cent of the total budget (this figure can vary substantially depending upon definitions). The dividends from improved shipyard productivity are warranted, but this is only part of the overall value proposition.

Similar to the US Defense initiative, a thorough assessment of Australian shipyards and modular block manufacturers involved in naval shipbuilding would be beneficial for two reasons: firstly, it would erase myth and, secondly, provide motivation for improvement. Initial benchmarking would be naturally followed by an improvement program and further benchmarking. With ASC about to start construction of the first AWD hull blocks along with two sub-contracted manufacturers (BAE Systems and Forgacs), now is an ideal time to start data collection.

As an indication of the gains to be made, the FMI report observed that ‘if US shipyards realised the full potential of their manufacturing best practices and were able to operate at core productivity, their actual productivity could improve by as much as 50 per cent – and the best would be within the range of international shipyards’. Establishing a data-based, accurate reputation for Australian naval shipbuilding is important for decision making and all involved.

The results of this survey would need to be semi–public, they need to be available at least to decision–makers in Canberra (companies always get their own results). A more mature approach would be to have the general results openly discussed, in terms of how the Australian naval shipbuilding industry as a whole is performing. The focus of a mature conversation would be on the strength of commitment to improve, details of improvement programs and not a spat between shipyards about who was more efficient in the past.

Improvement programs need to be targeted at the specific weaknesses of each shipyard, rather than a single brushstroke across the naval shipbuilding industry. As a result of its 2005 assessment, the US Department of Defense prepared a $US140 million investment program that spanned most of the benchmarking groups and elements. Notable targets were: improving design for production; enabling enterprise interoperability with design/production data; using advanced material handling; and developing outsourcing strategies.
10.1 Rationale for Rolling-Build Programs

10.1.1 The concept of rolling-build programs (a process that does not have a defined end point) draws together factors covered in the previous sections of this discussion paper to form scenarios that potentially offer better value for naval capability. The concept is not new, and it is part of the rationale underpinning the Defence White Paper call for a build program of 20 Offshore Combatant Vessels. The Defence White Paper says:

*The Navy currently operates four relatively small fleets of vessels for important tasks such as offshore resource protection, border security, hydrographic and oceanographic environmental assessments and clearing sea mines. This significantly increases whole-of-life ownership costs and personnel overheads...*

*The Government has therefore decided that Defence will develop proposals to rationalise the Navy’s patrol boat, mine counter measures, hydrographic and oceanographic forces into a single modular multi-role class of around 20 Offshore Combatant Vessels combining four existing classes of vessels. This has the potential to provide significant operational efficiencies and potential savings. (Australian Government, 2009, page 72-73)*

10.1.2 There have also been calls for a rolling-build program for submarines; for example, in a submission of the Submarine Institute of Australia to the Defence White Paper Community Consultation Panel. In discussing some of the acquisition aspects of the future submarine in a speech to the Sydney Institute on 4 November 2009, The Hon Greg Combet AM MP, Minister for Defence Personnel, Materiel and Science, identified some of the significant benefits of a rolling program of 12 boats including ‘...to support a more sustainable industrial design, skills and maintenance base...’. He also identified the need to consider building this number of boats in batches and the benefits of the design capability being collocated with the construction facility.

10.2 Long-Term Planning

10.2.1 The report of the 2006 Australian Senate Inquiry into Naval Shipbuilding, *Blue water ships: consolidating past achievements*, recommended:

*Government make a public commitment to maintain Australia's naval shipbuilding and repair industry. This commitment to be supported by improved long-term planning of naval shipping needs in order to maximise economies of scale and provide continuity for the broad but specialised design and construction skills required for a healthy industry over the long term. (Australian Government, 2006)*

10.2.2 The call for more long-term planning has been frequent, but is most often about smoothing future workload, rather than a direct rationale for finding greater value. The two are related, but a smooth work profile alone does not guarantee greater value. Rolling-build programs are not about long-term planning, they are about building more ships in a program, and this includes continuous build programs.
10.3 **Productivity and Efficiency**

10.3.1 A fundamental principle of shipbuilding, previously mentioned, is that the labour resources required to produce a ship reduce for each ship in a series. Using the Weight Based Estimate method, the following graph shows the prediction for production resources for a warship of 5,000 tonnes Lightship Weight-core productivity is assumed, the data does not include adders (see Section 4.3.2).

![Shipbuilding Learning Curve – Core Productivity](image)

10.3.2 As discussed in Section 4, great care is needed in using the data. These numbers are based on Cost Estimating Ratios for a particular scenario: shipyard, era and warship design. The value in presenting this data is not the precise numbers – it is not a quote. The data is valid for examining trends and comparing outcomes of similar scenarios. What the data shows, which is typical, is that it takes about 84 per cent of the effort to produce the second five ships compared to the first five (this is the recurring production effort, not non-recurring engineering or machinery or material).

10.4 **The Impact of the Production Learning Curve**

10.4.1 The Defence White Paper states that the Government will acquire three AWDs and eight Future Frigates, which will be ‘larger than the ANZAC Class’. Given a requirement for a fleet of 11 warships, what is worth examining are the opportunities with the new Future Frigate if a rolling-build program was considered. The scenario to be examined is the production of a total of 11 warships, in different combinations of AWDs and a new warship.

10.4.2 For this evaluation, the assumption is the Future Frigate has a Lightship Weight of about 4,000 tonnes, compared to the ANZAC Lightship Weight of about 3,000 tonnes. The analysis also assumes a shipyard production adder of 20 per cent is applied for the new class (this is not non-recurring engineering, see Section 4.2). Also, the AWD data used below is the output of a Weight Based Estimate model, not ASC AWD Shipbuilder Pty Ltd data. Note also, the analysis uses consistent Cost Estimating Ratios, so is assuming the different build scenarios are similar in terms of design characteristics and production processes. The Cost Estimating Ratios would
possibly be different if different shipyards built the ships, or if the same shipyard adopted new technology or work practices for the new class. Block manufacturers who sub-contract to main shipbuilders also have their own, different Cost Estimating Ratios.

The two production curves are shown below.

What the data shows is that it takes about 28 million man-hours to build 11 AWDs in comparison to about 22 million man hours to build 11 new design warships as defined in Section 10.4.1. But the interesting data is what happens in building combinations of both warships. For example, if the scenario was to build three AWDs and eight new design warships, the model estimates about 26 million man hours are required for production. This later scenario does not take into account the effort required to design the new class of warship and the other non-recurring/non-production overheads of a second Defence Program (see Section 10.5 for discussion of these costs).

If the scenario was to build six AWD and five new design warships, about 28 million man hours would be required. This example starkly illustrates the benefit in production efficiency of long-build programs, it shows that the production effort required to build six AWDs and five smaller ships is the same as building eleven AWDs. Going beyond the equity in production effort, building 11 ships of one class avoids the very substantial engineering, non-production and duplicated costs of the second program, and the very substantial overheads and duplicated costs in sustaining a second class of vessel.

The Overhead Cost of Multiple Programs

Several sections in this discussion paper have covered non-production costs in naval shipbuilding projects. Section 4.2 described the different production and non-production elements of a warship design and build project. Section 8.2.2 described the relative cost of non-recurring engineering as typically being equivalent to the cost of one ship, and that this ratio seemed to be increasing with the ever-increasing complexity of warships. But the extent of non-production costs is probably a lot greater than the often-quoted headline of non-recurring design engineering.
10.5.2 In searching for opportunity to improve value in naval shipbuilding in Australia, one question to be answered is: does government achieve better value by running one program building one class of warship for the total number of warships required, or two programs building different classes of warship?

10.5.3 In part the answer could be obtained by seeking valid, firm prices in committed offers from the different contenders, but the whole answer also requires the calculation of the Commonwealth’s differential costs. A price-based approach also requires absolute confidence that all risk has been captured and there are no emergent costs incurred by government, which is a very difficult caveat to address. Most importantly, what must be added to the calculation is the impact on sustainment and the bottom line in total cost of ownership.

10.5.4 In comparing the acquisition cost of running one versus two programs, it is important to distinguish all costs associated with running a second Program, as opposed to activities that are just non-recurring or non-production. Activities can be recurring in one program, but still be duplicated costs between two Programs. In the comparison, it is also important to include indirect or hidden costs, which are ultimately borne by government.

10.5.5 In creating a second program, non-production and duplicated costs in the preliminary stage up to contract award must factor in:

- Government (Defence-CCDG) definition of the new capability required and preparation of the Capability Definition Documents, which are the Operational Concept Document, Function and Performance Specification and Test Concept Document.
- Industry business development and marketing activities.
- Government and industry involvement in any concept definition studies.
- Government (Defence-DMO) development of acquisition strategies and preparation of source selection documentation, which includes draft condition of contract and engineering specifications.
- Government first pass activities.
- Industry preparation of tenders.
- Government evaluation of tenders and possible further industry engagement to better define requirements and tenders.
- Government second pass activities.
- Preparation and negotiation of final contract, including conditions of contract, final capability and engineering specifications, price, etc.
When the contract is awarded, the non-production and duplicated costs involved in operating a second program, including government and industry activities, are extensive and include:

- Establishment and operation of a second program office.
- Establishment and operation of a second project office.
- Advertising and recruiting costs.
- Office space, computer networks (classified and unclassified), software applications, and other substantial infrastructure costs.
- Development of the large suite of project control plans, such as risk management plan, systems engineering management plan, security plan, etc.
- ITAR and Intellectual Property management.
- Staff management and accounting systems.
- Legal costs.
- Prime contract management.
- Sub-system and equipment specification and tender preparation, tendering, source selection and contract negotiations and award.
- Supplier and sub-contract management.
- Financial control and reporting.
- Development and approval of test and evaluations plans, test procedures and execution.
- Development and approval of technical integrity and other certification plans, and execution.
- Basic administrative functions.

There are also hidden and indirect costs. For example, one project to build 11 warships has a very different risk profile from two projects building a total of 11 warships. The aggregate risks of a long, single project should be substantially lower than two, shorter projects. Consequently, the contingency budget and fee should be lower in the single project (if all negotiated at the outset, not necessarily true for a contract extension).

The costs duplicated between multiple programs are very pervasive, and care is needed not to limit their calculation to headline activities like design engineering. As stated above, the overhead cost of operating multiple programs is probably a lot greater than the basic non-recurring costs often quoted. The extensive sustainment implications of multiple programs are discussed in Section 10.9.
10.6 Warship Platform Systems Cost Behaviour

10.6.1 The material required to build a warship platform system includes: hull plate; steel shapes; gas turbines; propulsion diesel engines; gearboxes; shafts; propellers; platform management system, diesel generators, switchboards and distribution systems; heating, ventilation and air conditioning; firefighting and damage control equipment, and galley, dining, accommodation and recreation facilities.

10.6.2 Not all these costs are linearly dependent upon ship size. The amount/cost of material required for the hull and some platform sub-systems does vary according to the volume of the ship, such as firefighting, ventilation and electrical distribution equipment. For two warships in the size bracket mentioned, other systems costs are much less size dependant, such as gearbox, shafts, propellers, platform management system, gas turbines, and propulsion diesel engines. Costs for the propulsion system tend to increase in steps with increasing ship size, the underlying logic being that a particular configuration can be up or down-rated for a range of different ship sizes, but eventually as size increases a new, larger configuration of plant is required. The cost behaviour is illustrated in Figure 13.

10.6.3 There are of course many variables in this analysis, and the detail of each design needs to be studied before forming conclusions. For example, if one of the ships did not have the same speed requirement, this would reduce the propulsion power requirement and reduce costs (but not linearly).

10.6.4 In comparing the benefit of building one versus two classes of warship, as discussed in Section 10.4.4, the cost of equipment and materials for a single class can benefit from bulk purchase orders. In basic commercial terms, the unit price of platform equipment does reduce for larger orders. In the scenario being discussed, the relatively lower cost of smaller platform equipment in the new class of warship is offset by price efficiencies of bulk orders for the larger warship equipment. Precise modelling and pricing would be required to determine the magnitude of cost changes and net result.
10.7 **Platform System Design Adaptability**

10.7.1 The matter of choice about combat system capability raises the opportunity of separating the combat system from the platform system during analysis and planning. A basic scenario is to run a rolling-build program for a particular platform and, if capability planners so desire, change the combat capability in different ships or groups of ships.

10.7.2 One of the very clear trends in modern warship programs is the concept of building platforms with different mission roles. The European FREMM program is building 20 or more warships of the same platform design, but with different combat system configurations for three different missions: anti-submarine warfare, surface warfare and area air warfare. The US Navy LCS program builds a platform with changeable mission modules. As stated earlier, this is also the approach with the new Offshore Combatant Vessel for Australia.

10.7.3 The Spanish F-100, which is the platform design for the AWD, can also be adapted for different combat systems and capability. The combat system in the Spanish F-100 warships is very different from the Australian AWD, even though both are centred on a US Navy Aegis Combat System. In terms of platform design and performance, the Spanish operate the F-100 hull design with a full load displacement of about 6,000 tonnes. Australia will operate the AWD with full load displacement of about 6,500 tonnes and the theoretical upper design limit is a full load displacement of about 7,000 tonnes. This is typical: all warships are designed for different load conditions and during their service life at sea are always operating under different load conditions as fuel, ammunition and other stores are consumed and re-stocked.

10.7.4 In the design of a warship platform, the minimum and maximum design loadings can cater for very different combat systems. The notion that a platform must be fitted with an identical, ‘fully capable’ combat system is not valid. The capability of a combat system could be reduced and still be installed in the same platform (it is not uncommon to install ballast in warships).

10.8 **Mission System Flexibility**

10.8.1 Building a series of platforms for different missions with different combat systems has a number of advantages. Building a rolling series of platforms attracts productivity benefits and reduces non-recurring costs as discussed above, provided the right commercial arrangements are in place. With a known platform in long-term production, the opportunity arises to plan the introduction of a new combat system with greater control of risk. The mature design of the platform noticeably reduces combat system development risk – and is a design constraint. Also, schedule risk is reduced by having the option to continue to deliver the current configuration until the new system is fully developed, tested and certified. The whole project depends less upon the readiness of a new system and is not stressed by the pressures of a short schedule. There are of course non-recurring engineering costs with each new combat system, but they are substantially lower than for an entirely new ship.
10.8.2 This risk control has been used very successfully by the US Navy on the DDG-51 program, where it uses a philosophy of ‘design a little, build a little, test a little’ across groups or ‘flights’ of warships. What this means is the program keeps producing current configuration systems until a new version is proven ready for production and delivery, then they build the following flight of warships in the new configuration. This incremental approach with a rolling-build program also avoids the ‘big bang’ trying to insert a major suite of changes into ships in a short-run program. The FREMM program is likely using a similar philosophy. This concept has limits, and careful planning and contingencies are still required.

10.8.3 An advantage of an ongoing platform-build program is that export units can be taken from the production line if government chooses. Combat systems such as Aegis are subject to tight international controls and not freely exportable.

10.9 Benefit to Total Cost of Ownership of Commonality

10.9.1 Airline companies recognise that one of their major cost drivers is not the number of aircraft they operate, but the number of types of aircraft they operate. For machines like warships and aircraft that require substantial infrastructure to sustain, avoiding the non-recurring costs of extra machine types/classes results in a substantial saving. Without going into every detail, there are substantial savings in avoiding duplication in areas such as:

- Training equipment; training facilities (especially expensive ship or combat system simulators), training staff; courseware development and courseware maintenance.
- Spare parts management, codification and storage, including fewer rotatable pool items and strategic spares holdings.
- Land-based test sites, which includes operational hardware and software; and software testing, modification and certification.
- Systems engineering.
- Fleet engineering support.

10.9.2 A benefit of rolling-build programs – if they reduce the number of classes of warship – is substantial savings in sustainment costs. This applies whether the rolling-build project is for the entire warship or just a common platform system. The savings are generated by not having to establish the infrastructure required to support each design, and by avoiding the annual operating expenses of a second sustainment system. One common rule of thumb is that sustainment costs are twice the acquisition costs of a complex system like a warship. Not all of these costs are avoided by having one class of warship; each vessel and each crew have their attendant maintenance and training costs. The duplicated costs and overheads are significant, however, and infrastructure for smaller classes of warship is typically not fully used. With one class of warship such additional infrastructure investment is not required, so the savings are likely to be very substantial.
The benefits of commonality in the fleet are frequently acknowledged, but how well the real benefits are understood is questionable given the ‘uncommonality’ that exists in the fleet. Over the years, various policies have been formulated to promote commonality of systems across the fleet, but with minimal effect. The nature of single, short-run projects with separate accountability is that they deliver uncommon systems. One of the more significant benefits of a rolling-build program is the enforced commonality of systems, and the substantial savings that accrue.

**Rolling-Build Program Summary**

This narrative is not intended to be an exhaustive analysis of the cost of naval shipbuilding in Australia. What the narrative aims to highlight is that there are many non-linear costs in naval shipbuilding, and assumptions such as bigger ships always cost more than smaller ships can often mask counter-intuitive solutions that offer better value. A general awareness of some of the factors such as learning curve gains is insufficient and needs to be replaced with more accurate modelling of acquisition and sustainment costs and, in particular, options and scenarios extending beyond single warship classes/capability elements.

The factors and general modelling discussed above suggests a rolling-build program of one class of warship could substantially reduce costs to the conceivable point that it is no more expensive to build one class of more capable warship than it is to build a mix of capable and less capable warships. The more popular terms of larger and smaller warship are avoided. Certainly, when sustainment costs, (and hence total cost of ownership) are also considered, the investment proposition in favour of one class of warship is strongest. From the capability perspective, a fleet of more capable warships at the same or lower cost is better value.
11.1 Defining Common Systems

Section 10.9 described the benefit of equipment commonality that results from a rolling-build program of a single class of warship. The principle is not dependent upon a long-build program. Government may decide to build different warships for different purposes, but ownership value can still be improved by using common systems.

11.1.2 The value principle underpinning common systems is to avoid the non-recurring and duplicate expenses of different systems and different programs. Those costs include design, software development, testing, certification, security and intellectual property control, training courseware and infrastructure, stores management, etc.

11.1.3 From a systems perspective, value can be improved by driving common systems into different hull designs across a fleet. The in-between solution is to decide upon a common platform, fitted with different combat systems according to capability requirements. But even in this multi-mission configuration, common sub-systems within the mission system attract the benefits of commonality e.g. integrated bridge and communications sub-systems.

11.2 Common Combat Systems

11.2.1 In comparison to platform systems, combat systems typically have a much higher proportion of development costs. This is because the resources required to develop, test and certify complex, real-time software systems are considerably greater than the computer hardware that hosts the final software program. Additional copies of the software and hardware are also relatively inexpensive. This does not diminish the benefits gained from a common hull or any other measure, but it is the reason many navies are aiming to operate one core combat system across their fleet.

11.2.2 The US Navy call it Open Architecture, the Spanish Armada refer to it as SCOMBA (Spanish Combat System). These common combat systems are not a single configuration; they are more a library of elements, which are assembled with standardised interfaces for different warships. An earlier example of the principle is evident in the Aegis Combat System to be installed in the AWD. This system has seven major variants fitted to more than 100 warships in six navies (US, Japan, Spain, Norway, Korea and Australia).

11.3 Common Platform Systems

11.3.1 Platform systems tend to be unique to each hull design, because the designers tend to come from different countries and each has its own network of machinery suppliers. This sort of equipment includes diesel engines, gas turbines, pumps, motors, electrical generation and distribution, ventilation fans, lighting, etc. For example, in the ANZAC design, Blohm+Voss used German MTU diesel engines, whereas in the Spanish F-100, Navantia use Caterpillar engines manufactured in Spain. Commonality in platform systems is achievable, but it has to be driven. Commonality policies that apply to individual projects have not worked for a range of reasons.
If the aim was to have a common platform management system across all RAN ships, then it has to be mandated and one practical step is to have a separate office manage this sub-system for all projects. Large platform systems such as: propulsion diesel engines; gas turbines; platform management systems; fire fighting; damage control; heating, ventilation and air conditioning; electrical generation and distribution are prime candidates for commonality. Again, the configuration on different ships would not be identical, but would come from a common family.

The Spanish Armada have all diesel engines under one sustainment contract because it results in efficiency and innovation. For the same reasons, the Armada has developed its own Integrated Platform Management System (IPMS), which is mandated for all ships including retro-fitting to old classes. These sorts of strategies meet opposition when introduced, but the long-term dividends are substantial. For the Armada, the cost of introducing a new platform with an IPMS is now relatively low and so are the incremental sustainment costs.

**Common Platform – Single-Program Model**

There are two basic project models for building common platforms with different combat systems:

- There is one principal program that builds the platform in one consolidation shipyard and has different arrangements for the supply into that process of the different combat systems.

- There are two programs using a common platform system design (the single program model).

This section deals with the first option. In producing common platforms with different combat systems, it is of course conceivable for one program and one supplier (prime contractor or alliance) to deliver two types of warship. This offers some opportunity to avoid duplicated costs. Which model is chosen depends upon a range of factors across government and industry, some of which were touched on in Section 7.

For the single program model, there are two approaches to the delivery of the different combat systems:

- The program could use one Combat System Integrator at the Tier 2 level, which, through the involvement of different Tier 3 suppliers produces different configuration combat systems.

- The program could use two (or more) Combat System Integrators at the Tier 2 level which use their own network of Tier 3 suppliers to produce the required combat systems.

The choice of which model to use can depend on the particular operational requirements of the different combat systems. If the requirements are vastly different, then different suppliers may offer a better value solution, but using different Tier 2 Combat System Integrators results in equipment which is not common and is counter to producing better value for total cost of ownership by employing the commonality principle. There are other advantages such as a lower overhead and reduced duplication in acquisition and sustainment by involving only one designer.
11.5 Common Platform – Multiple-Programs Model

11.5.1 Section 12.7 examines a project model that involved a Platform System Engineering Agent (PSEA). The use of a PSEA makes it much more straightforward to set up a single project or multiple projects building a common platform with different combat systems, with construction in different shipyards if desired.

11.5.2 Without a PSEA, the general scenario is that a project will have a platform designer that produces a high-level (functional) design and the shipyard does the remaining engineering to produce it own facilities using its particular processes. The functional design does not contain enough information to allow a second shipyard to build the ship, and the information subsequently produced by one shipyard is suited to their purposes and is proprietary. Compared to the functional design role, the more extensive PSEA role goes further in the engineering process to the point where the PSEA, working in concert with each shipyard, can efficiently and effectively produce the tailored data required by each shipyard to build the common platform. The shipyards will still engineer their final production documentation.

11.5.3 In terms of project models, there is variation in how a PSEA is placed to support two programs using a common platform. The PSEA could be engaged principally by one program and produce data for a second program, or the PSEA could be separately contracted by the customer to support the two programs. The arrangement is illustrated in the following figure – repeating that this is but one example of many different arrangements that are possible. The model shows the PSEA as the single procurer of major machinery systems, not shipyard materials, because in splitting the procurement task for common systems is likely to be more costly and less effective at achieving maximum commonality.

Figure 14 A Common Platform Business Model
In this and other multiple project scenarios, there are two ways the participants can be selected. One is to allow each team (combat system integrator and shipbuilder) to independently form and bid for the work; the second is for the Commonwealth to control the selection of the combat system integrator and shipbuilder separately. While not definitive, recent experience with complex naval vessel programs such as Collins and ANZAC suggest a better outcome is achieved for the Commonwealth if the Commonwealth makes the team selections.

 Achieving Commonality

The only real opportunity to achieve commonality is in the formative stages of a new program, it is not something that can be effectively done to an existing fleet. The choice of Navantia solutions for both AWD and LHD did achieve a commonality in those two platform systems, but the separation of the projects will result in variations.

For new acquisitions, early decisions can be made to mandate common elements, from a selected range of sub-systems all the way through to a common platform. The sort of sub-systems that are relatively easily adaptable to a different hull and combat system designs are communications, electronic warfare, navigation, integrated bridge, integrated propulsion management, electrical distribution, heating ventilation and air-conditioning, etc. Some of these systems can also be used in submarines, support ships, patrol boats and aircraft.

The use of standard systems can be theoretically tested in a source selection process, but in practice it is not straightforward. While bidders could offer prices for their own equipment configurations as well as a configuration that uses standard sub-systems, the results can be distorted through lack of information or willingness. Bidders unfamiliar with other systems will increase risk factors and it is very difficult to prove the final answer. Also, the real gains come from sustainment, not acquisition, where standard systems dramatically reduce costs as discussed in Section 10.9. The solutions are most effectively tested through independent modelling.
12.1 Introduction

This section draws on the earlier discussion on business models (Part II) and engineering in naval shipbuilding (Part III) to discuss further models that might be used for naval shipbuilding projects. There is no best model that suits all projects. The circumstances of each project require assessment in choosing the right model for that project.

12.1.1 The following discussion is more about the architecture of projects than it is about how the participants are selected. The total cost of ownership to government of the navy fleet is more affected by choices such as rolling-build programs and commonality than by the choice of competitive or directed contractor selection. These choices are not inter-dependent, they are independent choices that can be and should be made according to the different circumstances, and can combine under all different arrangements.

12.1.2 The following discussion is generally about single projects, but the arrangement between projects (Defence Naval Ship Programs) is also important in determining overall value and this will be discussed in Section 13.

12.2 Modern Production Techniques

12.2.1 Modern shipbuilding techniques involve the manufacture of hull blocks and modules, which are then consolidated into the complete hull. The advantage of block construction is ease of manufacture, unhindered construction, parallel construction and distributed construction. Building in blocks allows workers much better access to the construction space, materials and tools, use of overhead cranes and other support machinery, all in workshops not affected by weather. Blocks are usually inverted when working on deckhead fittings because ‘down-hand’ work is much easier and efficient than working over head. Trying to do all this work inside the enclosed, small spaces of a warship interior is much less efficient. Current world’s best practice targets are to complete 80-85 per cent of work (man hours) prior to consolidating a block, a substantial shift in work to a much more efficient environment.

Figure 15 AWD Block Outsourcing Plan
12.2.2 Block construction also allows blocks to be manufactured (including fitout and testing) in parallel. In practice they are not all done simultaneously in separate locations, but there is a considerable amount of parallel production. In older ship construction methods, work had to progress one deck level at a time from the keel up. The use of more than one location provides the opportunity for alternative work plans if one location has difficulty and is delayed, which reduces project risk.

12.2.3 Past naval shipbuilding projects have typically involved one shipbuilder, with most construction done at their main shipyard. The block construction method also allows the outsourcing of a considerable amount of the fabrication work from the ship consolidation yard. In the AWD program, 70 per cent of the total of 66 hull blocks is being outsourced from the AWD Alliance shipbuilder (ASC). In new contracts, the level could be 100 percent.

12.2.4 According to public ASC presentations, AWD block construction represents 33 per cent of the shipbuilding $1.25 billion procurement budget; materials is another 35 per cent. Caution with these numbers is required because this is not the total shipbuilding budget. What is not included in the procurement budget is the core budget for the blocks that ASC will fabricate (about 30 per cent) and the effort required to consolidate the ship, that is, connect the blocks, install long-run power cables, connect up ventilation, set to work, test and trials, etc. Note though, much of this work is outsourced to smaller suppliers. The data suggests that a large portion of shipbuilding budget is outsourced, much of that using competitive tendering.

Figure 16 AWD Alliance Roadshow 2007 Shipbuilding Procurement Breakdown

- Block Construction 33%
- Major Equipment 22%
- Commodity Materials 16%
- Services (Other Fabrication) 5%
- Intermediate Products 3%
- Block Transportation 3%
- Facilities 6%
- Navantia 12%
12.3 Combat System Engineering

The situation is similar with combat system work in a major warship project, where much of the effort is outsourced. In a typical warship program there is a lead combat system engineering company that controls the architecture of the system, oversees system integration and manages full system test and certification. The supply of sub-systems such as missile launchers, air search radars, surface search radars, navigation equipment, gun fire control systems, missile fire control systems, gun mounts, short-range defence systems, communications, electronic warfare, etc., is typically done by a range of vendors. The lead combat system company may provide some of these sub-systems, and may do some of the interface development.

12.3.2 In the case of AWD, Raytheon Australia is the ‘Combat System Systems Engineer’ and the large majority of the combat system budget is outsourced to other combat system engineering and equipment suppliers. Except for the core Aegis Combat System, which has to be procured Government-to-Government, sub-system outsourcing is by competitive tender.

12.4 Extent of Sub-Contracting

12.4.1 In 1989, the Australian Government awarded Amecon (later Tenix and BAE Systems) the prime contractor for the design, construction, test and delivery of 10 ANZAC Class warships, including two for the RNZN. The 2000 Tasman Asia Pacific report, Impact of Major Defence Projects: A Case Study of the ANZAC Ship Project, found that:

- Over 1,300 Australian and New Zealand companies were involved in the project.
- Over 60 per cent of sub-contractors were Australian.
- Victorian firms received over three-quarters of the value of Australian sub-contracts.
- Over 75 per cent of Australian companies involved were from the manufacturing sector.
- Over 90 per cent could be consider small to medium enterprises (SME).
- Australian and New Zealand content equates to about 72 per cent of the contract value (then $4 billion). (Tasman Asia Pacific, 2000)

12.5 Past Projects Model

12.5.1 Past business models including prime contracts and alliances (Tier 1) have provided for considerable outsourcing at Tier 2 and lower levels, much of that by competitive selection. The combat system element of those projects typically involved multiple suppliers for sub-systems and equipment, and the same for the supply of machinery sub-systems and equipment. The following figure adds these lower tiers to the business models presented earlier in Section 5.6 (see Figure 8 – Traditional Prime Contractor Business Model and Figure 9 – AWD Alliance Business Model).
12.5.2 Modern shipbuilding processes such as block fabrication enable greater levels of production outsourcing and competition. The Government could require competitive tendering of all hull blocks and define the core work of the main shipbuilder as ship consolidation, which is a substantial and challenging task in itself.

12.6 Project Model – Platform System Engineering Agent

12.6.1 Major naval shipbuilding projects such as ANZAC, Collins and AWD have all involved the selection of an overseas platform/hull design and the engagement of the parent warship designer, all foreign companies: Blohm+Voss of Germany, Kockums of Sweden and Navantia of Spain. The role for these companies has been generally to supply the initial hull design, some CAD models and some production data packs and drawings (it varied between the contracts). At some point during the project, the Australian shipbuilder takes over control of the design.

12.6.2 There is an alternative model for the management of the platform design, and that is to appoint what has been called a Platform System Engineering Agent (PSEA). This role is not dissimilar to the current role in defence projects of the combat system integrator, also known as the Combat System Engineering Agent (Lockheed Martin’s title in the US Navy Aegis Combat System Program) and Combat System Systems Engineer (Raytheon Australia’s title in the AWD Program).

12.6.3 Compared to the past role of foreign warship designers described above, the PSEA role has a greater, much more demanding and enduring scope. The PSEA develops or supplies the platform system design, engineers all the machinery sub-systems, controls the configuration, designs any modifications required, conducts production engineering in concert with the shipyard, produces production data packages, and manages the engineering aspects of set to work, test and trials, and delivery. As the design authority, the PSEA supports certification, verification and validation of the platform system design.
Whilst the PSEA task involves mechanical, electrical and other engineering categories used in non-defence industries, at the core, designing warships is a unique defence engineering challenge. In designing a warship, everything has to fit in a very small space, must operate through the harsh environment at sea, and be able to survive battle damage. The skills required to do this job well are unique, and experience is very important in these relatively small, concentrated teams.

Importantly, as the designer, the PSEA usually carries accountability for platform system performance, and consequently usually manages sub-system selection and sub-contracts for equipment supply. As with the combat system, equipment supply could be done directly by the prime contractor, but this complicates accountability and that regime needs very careful design.

The partitioning of platform system engineering from construction provides further flexibility with acquisition strategies. Engaging the PSEA and shipbuilder separately allows different source selection and contracting models to be used for each, and with different timing. This is valuable because these domains typically have quite different timetables, peak activity periods, risk profiles and market suppliers. The ability to engage the PSEA early in the requirements definition phase is a strong advantage. The combination of models are many; both the PSEA and shipbuilder could be competitively selected, or direct sourced, or a mix either way. They also can be engaged under different forms of contract.

The direction of PSEA work to selected companies sustains and develops key skills, and the higher risk associated with design and development work suits a more partnership-oriented contract model. Selecting companies to manufacture hull blocks is well suited to competition. While the selection of a main shipbuilder for hull consolidation also lends itself to competition, given a mature design, there can be strategic reasons to direct this work; for example, optimising infrastructure and investment in future productivity gains. Given a mature design, production work also lends itself to fixed-price contracting.
The PSEA role does not require the infrastructure or large workforce needed in the construction task. However, the PSEA does require a skilled and experienced engineering workforce, and the company does need a strong balance sheet if it is to carry accountability in a project. In Australia today, there are no companies with PSEA experience that could immediately fulfil this role. One reason, but not necessarily the only reason, is that past naval ship projects have not been arranged to incorporate a PSEA role. There are companies in Australia with the potential to fulfil the role.

One reason, but not necessarily the only reason, is that past naval ship projects have not been arranged to incorporate a PSEA role. There are companies in Australia with the potential to fulfil the role.

Traditional shipbuilding companies sometimes argue that they should be the PSEA. While the scientific domains are similar, civil, mechanical engineering and the tasks of functional design and production are different. There is good argument to merge the two roles into a shipyard, such as good integration of production engineering in functional design. There are also valid reasons to partition the two roles; one is a professional services role; the other a construction role requiring substantial infrastructure. They have different timing requirements in a project and lifecycle of a warship, they contribute very different risk profiles to a project and there is a different supplier base. The separation of the two roles also enables different acquisition strategies as discussed in Section 12.6.6.

As is discussed in Sections 12 and 13, having a PSEA can enhance commonality across different platforms and improve the value achieved in the acquisition and sustainment of all those platforms.

Project Model – PSEA and Two Consolidation Shipyards

One of the project models that a Platform System Engineering Agent enables is the use of two or more shipyards to build the same class of warship. The PSEA does enable other project models, and in particular other inter-project models, which will be discussed later in the paper. This description of a different project model is an example that highlights a scenario where the customer wants to retain an ongoing competition motivation.

Involving two shipyards in one project does add overhead costs: it would only be viable if those costs were offset by the gains created by the competitive force. With a PSEA controlling the design and production engineering data, it is possible to have two shipyards constructing the same class of warship. Another option is to have two shipyards consolidating the same class of warship, with all block manufacturing outsourced and competed. The outsourcing of block fabrication could be done separately by the two shipyards, or done centrally by the prime contractor with the fabricators supplying both shipyards. The business model is shown in the following diagram.
12.7.3 Using two shipyards loses some of the production learning gains that come with a single shipyard. But good management by the PSEA to monitor each shipyard, capture and pass on lessons learned mean there should be some crossover learning. The advantage of the two-shipyard model is that it creates ongoing competition (without the large overhead of two separate projects) and provides benchmark data to drive improvement in the other supplier. This ongoing benchmarking can work both ways with best-performance targets drawn from different elements in each shipyard and applied to the other.

12.7.4 The model can be altered by removing the single prime contractor such that the designers and shipyards are separately contracted by the Commonwealth. The reasons to do this are many and varied, but the issue that arises is unambiguous risk allocation. Done well, the separate contracts would still place considerable coordination risk with the Commonwealth. If the contracts were poorly prepared, the Commonwealth would carry the consequences of all problems.

12.7.5 This model does increase the number of major sub-contractors at the Tier 2 level, which does add a new set of overheads. Whether such a model produces better value than other models depends upon the circumstances. The choice is a trade-off between the overheads added and the costs saved by having competition in production activities (ship consolidation, block and module manufacture). This equation would suggest the model suits an industry with poor production productivity.

12.7.6 The prospect of establishing a new and separate PSEA organisation, instead of building on the experience and investment in, say, ASC to date (for submarines and AWD), could represent a higher risk. As identified at paragraph 12.6.9, integrating the PSEA as a division within the shipbuilder, provides the advantage of close integration and feedback of construction and project management experience/outcomes into the design and logistics support/maintenance process, particularly for evolutionary designs such as batches or ‘flights’. This would provide a good mechanism for cross-pollination of current and new submarine design skills into the surface warship environment for example in designing for shock and noise minimisation important to

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**Figure 19: PSEA and Two Shipyards Business Model**

- **Tier 1**: Commonwealth
- **Prime Contractor or Alliance**
- **Tier 2**: PSEA
  - CSI
  - Shipbuilder 1
  - Shipbuilder 2
- **Tier 3**: Machinary Suppliers
  - Combat System Equipment Suppliers
  - Hull Block Fabricators
  - Other goods and Services Suppliers
12.8 Driving Better Performance in Contracts

12.8.1 One challenge with rolling-build programs is how to ensure continuous improvement, or at least not permit a descent into complacency and institutionalised inefficiency. Given the uncertainties that inevitably exist at the outset of any major warship project, and design changes that invariably follow, a construction program over 20, 30 or more years is unlikely to suit a fixed-price contract. If one was attempted the various contingency budgets would be enormous and prices considerably inflated.

12.8.2 How the design of a warship is contracted depends largely upon risk and uncertainty, as discussed in Sections 5.3.3, 5.5.5, 6.2.3, 12.6.7 and elsewhere. If the design will be brand new, or is uncertain or unstable for any other reason, the work is not suited to fixed-price contracting (without substantial padding), and is more suited to some form of partnering contract. If the design was assuredly proven and stable, then fixed-price contracting for the non-recurring engineering work is more feasible if competition is obtainable. The issue of contract models for design and other non-recurring engineering is largely independent of the number of ships to be constructed, but the duration of the project and the associated period of those services contracts is a factor in contract model choice. The particular issue to be dealt with in rolling-build programs is construction performance.

12.8.3 An efficient rolling-construction program must rely upon regular and renewed performance targets. There are many different ways to treat this in contracting. One approach would be to contract for production of the first, say, two or three ships in order to establish a relatively stabilised production cost per ship. Then a target can be set to reduce the cost/price of successive ships, with the amount reset for each ship or set of ships according to the actual results. If successive ships were contracted at a fixed price, then the price discount might be set at, say five or 10 per cent per ship. If the contracting regime were some form of cost-plus, the new cost limit would be set with attendant pain-share/gain-share compensation arrangements. The simple lever to motivate improved performance is not to order follow-on ships until better performance is proven. In the two shipyard model, Figure 19, the option exists to compare the shipyards and award new orders to the best performing yard.

12.8.4 There are difficulties with this approach, particularly if there is a considerable overlap of construction work with hulls in series; shipyards do not complete one ship then start from scratch on a new ship. So efficiencies can be lost if orders are not well timed and bulk purchase discounts lost if orders are not placed for the full run of equipment. There is also always a risk that governments and their priorities change, and rolling build programs are suddenly terminated.
12.9 Common User Facilities

Common user facilities such as in Adelaide and Perth provide further opportunity for the project models discussed above where the PSEA manages the design/engineering of the platform system. These public facilities allow the ship consolidation role to be competed or changed, without incurring a change of location, general workforce or Tier 3 suppliers.

12.10 Small to Medium Enterprises (SMEs)

12.10.1 As the case study of the ANZAC ship project observed (Section 12.4), a warship project can involve more than 1,000 companies, the vast majority being Small to Medium Enterprises (SMEs). The 2002 Tasman case study of the Mine Hunter Coastal project (MHC) had similar findings (Tasman economics, 2002). Building a single class of warship does not diminish the volume of work available for Australian SMEs, although the ‘production line’ may consolidate the companies involved. On the other hand, the more predictable nature of business may see companies invest and an increase in SME involvement.

12.10.2 One of the other observations of the ANZAC study was that Victorian firms received over three-quarters of the value of Australian sub-contracts. This ‘halo’ effect was also evident in the MHC study, but more for services due to the nature of local industry in Newcastle, that is, non-Defence. With block outsourcing, or two shipyards, the work is nationally distributed and a number of ‘halo centres’ are created. Combat system work is typically removed from the shipyard and nationally distributed.
13.1 Maximising Opportunity and Value

The best way to achieve better value in total cost of ownership is to consider acquisition and sustainment arrangements across programs and across fleet units. It is beyond the scope of this discussion paper to discuss every aspect to improving value across this entire domain, but there are aspects to the previous discussion about project models that are worth examining in this broader context.

13.2 Achieving Greater Fleet Commonality

13.2.1 Having made the case to minimise the number of classes of ship, which promotes commonality, the next step is to find ways to achieve greater commonality across necessarily different classes of naval ship: warships, submarines, support ships, amphibious ships, etc. The announcement in the 2009 Defence White Paper to procure 20 offshore combatant vessels reflects a decision to minimise classes of ship by bringing together four previously different classes: patrol boat, mine counter measures, hydrographic and oceanographic.

13.2.2 While the characteristics of warships, submarines, support ships, and amphibious ships, etc are very different, there is still considerable opportunity to promote commonality across these naval ships and achieve savings in total cost of ownership. Apart from the hull shape, there is no reason why many of the machinery systems in surface ships could not be common. Obviously the larger ships would require larger ventilation systems, but the components could be identical. Alternatively, as an example, if different size (physical and power rating) electrical generators were required, commonality could be optimised if they came from the same family of machines, which would promote commonality in piece parts, maintenance routines, training, etc.

13.2.3 Previous sections in this discussion paper have made the point that the only really effective way to achieve commonality is not by policy, but by having a common platform and starting at the very beginning of the machines creation – at initial design. What really underlies this rationale is the existence of one designer. In theory, if one organisation designed all platforms in the fleet, with sensible guidance, that would achieve maximum commonality across different platforms. In practice, this is not an immediate objective.

13.2.4 What can be considered is to look at the broad categories of naval ship and architect the different acquisition arrangements to promote a sensible growth path to commonality, while preserving some flexibility in the establishment of projects over long and different timescales. Figure 20 presents the basic model of a naval shipbuilding project in a different format, which should be explained before presenting the broader inter-project model. In this vertical depiction, the tiers have remained as Tier 1, the prime contractor or alliance, Tier 2 – the major participants of shipbuilder, CSI and PSEA (who may also be alliance participants or a separate division of the shipbuilder/prime) and Tier 3, the various goods and services sub-contractors.
In the following diagram, this vertical model has been used to illustrate multiple programs covering the current and future defence acquisition programs and naval ship categories of destroyers, frigates, submarines, support ships, amphibious ships, offshore combatant vessels. These partitions can be done differently; for example, separate sealift ships, and other classes added. Importantly, the domain colours have been replaced with colours that illustrate where a common supplier could be used for the purpose of creating systems commonality in the pursuit of better overall value in total cost of ownership.

The rationale in this version of the diagram aims to promote commonality across some platform systems by using the same PSEA for destroyers and (future) frigates, and the same PSEA for support ships and amphibious ships. To be clear, this is not the same PSEA for all; they could be separate companies or the same depending upon selection processes. Note that if offshore combatant vessels were split into its original four classes, the diagram would show four projects (columns) with a common PSEA (and possibly CSI, but that is yet to be finalised for that program).
There are many other options to designing this multiple project model, and most if not all suggestions would meet opposition from some quarter. Commonality is a major driver to reducing total cost of ownership; it produces savings in acquisition and considerable savings in sustainment costs. Taking that principle further in this model, the same PSEA could be used for submarines, destroyers and frigates. While they do involve many different sub-systems, they have similar high-density design characteristics in comparison to support ships, amphibious ships and offshore combatant vessels, and the destroyer/frigate design could learn much from submarine design for minimised noise and high shock tolerance, for example. Given the benefits of learning from the high density and complexity of the future submarine design and transferring this knowledge into the various warship designs, the platform system engineering agent could be developed from the ASC teams engaged in both current and future submarines plus AWD production design. The support ships, amphibious ships and offshore combatant vessels tend to be more commercial in design and could also be combined under one PSEA. In terms of combat systems, the CSI for the destroyer and frigates could be the same, as they are (or can be) very similar systems in capability and design terms. For the same reasons, the CSI could be the same for support ships, amphibious ships and offshore combatant vessels. Whether the submarine CSI could be the same as the surface ship CSI requires further analysis, but in theory it could be worthwhile to make this connection.
13.2.8 The commonality principle applied so far here has the aim of creating common systems through common designs and systems engineering, remembering the PSEA and CSI engineering roles go much further than just functional design. But the objective of achieving better value in naval shipbuilding also suggests that the ship consolidation and block manufacturing roles could be common for common platforms. See for example the discussion of shipyard productivity in Section 9. This is not a claim that such production arrangements could immediately produce the best value outcome; the right arrangement needs to be proven by further modelling and would take time to achieve.

13.3 Tier 1 Role

13.3.1 Whether a prime contractor, an alliance or some other arrangement, the Tier 1 arrangement in this multiple program model has a critical part to play in achieving better overall value. If the Tier 1 supplier is a prime contractor and is one of the major Tier 2 participants, then commonality is achieved at the Tier 1 level mirroring Tier 2. If the Tier 1 supplier is the shipyard (consolidation role), it will be the same shipyard for destroyers, frigates and submarines in this illustrative example. This would achieve the sort of savings (including cost avoidance) discussed in this paper.

13.3.2 There is at least one alternative model for the Tier 1 role, which is the Engineer, Procure and Construction Management (EPCM) model discussed in Section 7.5. EPCM is the term used in the construction industry for a project where the prime contractor (or alliance participants) does not execute the construction but provides the professional services to engineer the solution and manage its construction. This does not mean the Tier 1 EPCM contractor would be the CSI or PSEA, they are a part of the Tier 2 team assembled. The Tier 2 companies could also be a Tier 2 participant, but the Tier 1 selection is on the basis of the company’s ability to lead the project (engineer, procure and construction management).

13.3.3 The EPCM model gains more traction where there are common user facilities available and the selection of construction companies (ship consolidation primarily) is not constrained by the need for infrastructure. In this scenario, a future project could involve a CSI and PSEA selected by the Commonwealth on the basis of the capability required, and an EPCM contractor selected on the basis of its ability to lead the project using the South Australian Common User Facility at Techport. Hull modules and blocks would be competitively outsourced. The ship would be consolidated on the Common User Facility by a company selected for the role, which could be ASC or another company that moves in to the role.
PART IV

Principles
A Set of Questions

The new Defence White Paper has and will continue to generate debate about a vast range of issues and claims. As stated in the introduction, this is a discussion paper that does not advocate a single capability outcome or industry objective – the paper aims to promote a broad, informed and analytical discussion about naval shipbuilding in Australia.

Part of this, or any, informed discussion that leads to meaningful results must be the postulation of specific questions and actions. This section is intended to present a modest set of questions about future naval shipbuilding, with the view of initiating discussion and analysis about actions that will produce the required capability with improved value for the taxpayers’ investment.

The sequence of questions that follow are in no particular order of importance, they are all important. They are also interrelated, but the complexity of the matter should not alter the need to deal fully with these sorts of issues.

Australian Naval Shipbuilding – How Many Suppliers?

The move by the British Government to direct supply of complex warships to one supplier will be seen as bold, possibly wrong, by many observers, but they cannot be accused of being hasty. The decision by the British Government followed extensive research for the MODUK into the challenges of sustaining skills in its industry. A strategic decision like this can only occur with dependable data.

In general terms, Australia faces a situation similar to the UK. This general likeness is not grounds for an immediate decision in Australia. One of the findings of RAND’s 2008 research for the MODUK was ‘that the supply-demand relationship is highly complex and that some technical skills are extremely sensitive to demand’. A similar effort to research the specifics of Australia’s situation is warranted. The Australian study obviously needs to cover all the naval vessel programs forecast by the Defence White Paper and all participants in the different industry structure that deliver these projects.

One of the microscopic characteristics often overlooked in the discussion about sustaining skills is that particular skills typically have a lifespan that is much shorter than the length of an entire program. The skills required to design a warship are very different from the skills required to construct the vessel – this is well recognised. Within a program like ANZAC or AWD, design engineering expertise has a major activity period of three to four years. This is followed, with overlaps, by a period of production engineering focus. The peak period for production skills obviously depends upon the number of ships ordered, for 10 ANZACs it was about 12 years and for three AWDs it will be about five or six years. The problem is that it is not sufficient to ensure programs run continuously end-to-start to sustain skills, it is necessary for programs to largely overlap so design periods are continuous. Without work and funding, these skills rapidly atrophy.
14.2.4 The AWD Program found that most of the skills used in the early design period of the ANZAC Program had disappeared because that project had moved into the final years of production. In contrast, the AWD Program benefited greatly from the direct transition of some combat system engineering skills from the Replacement Combat System Program for the Collins Class submarine. In its submission to the Defence White Paper, the Submarine Institute observed:

_The Defence Science and Technology Organisation working in conjunction with the USN and industry have demonstrated this capability in resolving many of the issues associated with the Collins program. Much of this Australian capability has now dissipated; it will require time and incentives to re-establish an indigenous R&D capability in a number of key submarine technologies. Given the lead times for such activities, this is now an urgent requirement._ (Submarine Institute of Australia, 2008, page 19.3.6)

14.2.5 But the issue goes much further than just ‘sustaining’ skills. The real issue is that while it takes time to recruit engineers and other skills to start up a major program, the real loss is that it is harder and takes much longer to build up a good team. In facing the enormous challenges of a major warship project, new teams are much less effective than experienced teams, and this ultimately increases risks, costs and schedules, and decreases quality outcomes. In _The Economics of Buying Complex Weapon Systems_, the authors observe ‘More specifically, experience, defined as previous participation in similar programs, appears to have a significant impact on supplier costs and capabilities (see, for example, Lorell, Sanders and Levalx, 1995)’ (Ergas & Menezes, 2004, page 5). The debate needs to turn from the passive notion of ‘sustaining’ skills, to the positive ambition of ‘exploiting’ skills.

14.2.6 The absence of a mature team with experience on multiple previous programs, or teams in different domains, is a very substantial loss. This is what leads to the question: should Defence direct complex warship programs to a single set of suppliers? This does not mean a single prime contractor necessarily; it could mean a single Combat System Engineering Agent and a single Platform System Engineering Agent, working with a single or multiple shipbuilders consolidating the warships. There are other variations of such models as discussed in Section 12. Obviously the same consideration needs to be given to the other types of naval vessel; submarines, support ships, etc.

14.3 **Australian Naval Shipbuilding – Should there be Rolling-Build Programs?**

14.3.1 In part this question has been answered by the 2009 Defence White Paper, which called for a class of 20 offshore combatant vessels to replace four existing classes of naval vessel. If these ships have a service life of twenty years and construction delivery settles into a cadence of one per year, then this can become a rolling program until someone decides a radically different capability is required. With a life of type of 25 years and a delivery interval of two years, the Future Submarine Program ends up in the same position. In discussing some of the acquisition aspects of the future submarine in a speech to the Sydney Institute on 4 November 2009, The Hon Greg Combet AM MP, Minister for Defence Personnel, Materiel and Science, identified some of the significant benefits of a rolling program of 12 boats including ‘...to support a more sustainable industrial design, skills and maintenance base ...’.
The question has not been answered for major surface combatants. The Defence White Paper calls for eight Future Frigates, ‘which will be larger than the ANZAC class vessels’. The White Paper states ‘The Future Frigate will be designed and equipped with a strong emphasis on submarine detection and response operations. They will be equipped with an integrated sonar suite that includes a long-range active towed-array sonar, and be able to embark a combination of naval combat helicopters and maritime Unmanned Aerial Vehicles (UAV)’. (Australian Government, 2009, page 71).

The obvious question to be asked is can this capability requirement be satisfied by an Air Warfare Destroyer, and if so, does the Australian Government achieve better value by ordering one class of 11 AWDs as opposed a mix of AWDs and new frigates? There are legitimate grounds for asking the question, but it cannot be answered without thorough analysis. Also, the analysis has to be dynamic, that is, it should explore different scenarios. For example, it may be that the AWD’s Aegis Combat System is too expensive for a lesser requirement (noting detailed requirements have not yet been approved), in which case another option to analyse is whether it is better value (total ownership) to use the AWD platform rather than a different, possibly new design for the Future Frigate. These questions are not easily answered.

The other equally legitimate way to consider the question of a rolling-build project for the Future Frigates is to ask whether the Future Frigate can be the basis for all future surface combatants? If the capability requirements were conceived with long-term warship requirements in mind, and the engineering specifications cleverly developed, the Future Frigate could be the rolling-build project for the AWD replacement and beyond. This approach recognises that there will be small-step continuous change in the detailed configuration of equipments and systems to address obsolescence and capability requirements but this would be conducted in a carefully risk-managed manner such as the evolving ‘flights’ of USN DDG 51 class ships.

Australian Naval Shipbuilding – Can Naval Shipbuilding in Australia Improve?

The answer to this question must always be yes. In businesses as large and long term as naval shipbuilding, there are always opportunities to be found.

With regard to improvement rates that have been proven; the research on global shipbuilding productivity produced by FMI for the US Navy in 2005 showed that the best-practice rating for the US shipyards surveyed had improved from 3.1 in 2000 to 3.6 in 2005 (First Marine International, 2005b). In terms of man hours per CGT (Section 4.4), this corresponds to an improvement in actual productivity (not core productivity; see Section 9.2.2) from a range of 55-95 man hours per CGT in 2000 to a range of 45-90 man hours per CGT in 2005. Best practice rating is a sophisticated FMI scale of reference ranging from one to five; see the US Navy (US Department of Defence, 2005) and FMI reports (First Marine International, 2005b) on Global Shipbuilding Industrial Base Benchmarking Study for further details.
14.4.3 At the same time in 2005, the average best practice rating for international (commercial and military) shipyards surveyed was 3.8. FMI’s research into South Korean shipbuilding provides more specific details of the improvements that industry achieved:

In 1992, the South Korean shipbuilding industry was operating at an overall use of best practice rating of approximately 2.8 while their overall productivity was approximately 45 man hours per CGT. By 1999, improvements in the South Korean shipbuilding industry had led to an overall use of best practice rating of 4.0, while at the same time driving the number of man hours to produce one compensated gross ton from 45 in 1992 to approximately 24 in 1999, a decrease of almost half. (US Department of Defence, 2005, page 26)

14.4.4 There are two aspects to considering the question about whether naval shipbuilding in Australia can improve. Firstly, there has not been an industry wide benchmarking study of shipbuilders and block manufacturers that establishes where Australia stands in terms of contemporary international performance. There needs to be such a study because without measurement there will be no realism about current performance, need/opportunity for improvement and future objectives. Studies by highly competent authorities such as FMI are also important because they produce detailed recommendations for actions to achieve better performance in each specific company or facility and a benchmark from which to measure improvement.

The second aspect to the question relates to the first point, which is why has there not been a publicly visible pursuit of benchmarking and improvement? The lack of vigour in this regard is notable. A debate about why this has historically occurred would be emotive and unhelpful. What would be helpful would be for the naval shipbuilding industry in Australia to publicly support such a study. As stated in Section 9.6.2, the first thing a benchmarking study does is erase myth. Today, the Australian naval shipbuilding industry has a patchy reputation. This often leads to calls for procuring naval vessels from overseas production lines. Measuring today’s actual productivity will not change performance, but it will establish a ground truth, identify specific areas for improvement and set a vision for future performance.

14.5 Australian Naval Shipbuilding – Can Equipment Commonality be Improved?

14.5.1 There is no disputing that the use of common systems and equipment substantially reduces total cost of ownership. Rolling-build programs inevitably force commonality into the fleet they create, but to date there has been no sure way of effectively achieving commonality by other means. The selection of the Navantia designed F100 and LHD did achieve commonality in platform systems, and this was due largely to the simultaneous timing of their second-pass decisions. This co-timing cannot be relied upon for future programs.
The question is how can the benefits of commonality be achieved across submarines, offshore combatant vessels, support ships and surface combatants? In a different environment, the Spanish Armada’s response is to direct all programs to a single supplier for warship engineering and construction. This may not suit Australia, and more analysis and discussion is required. One answer may be to appoint a single Platform System Engineering Agent to oversee the design and engineering of platforms, so that while hull shapes and shipbuilders will be different the systems inside will be common (or come from a common family with substantial component interchangeability and training commonality).

**Australian Naval Shipbuilding – Competition or Regulation?**

**14.6.1** How the Australian Government, the customer, commercially interacts with the Australian naval shipbuilding industry, the supplier, has a strong (not absolute) influence on the performance of Defence acquisitions. Sections 7 and 12 touched on various business models, but not the question of whether Australia should use an open-competition or regulated, semi-competition market for naval shipbuilding projects?

**14.6.2** Open-competition and regulated or semi-competitive methods suit different markets depending upon an array of variables including demand level; demand pattern; supplier availability; risk and uncertainty profiles, and constraints such as military classification and intellectual property restrictions. The question is not simply answered, and the choices not always easy to accept or implement.

**14.6.3** The choice between a open-competitive or regulated market is a complicated matter in an environment characterised by demanding military requirements and constraints, complex warship systems (hardware and software), enormous budgets, multifarious projects and very long timeframes. In a 2004 paper entitled *The Economics of Buying Complex Weapon Systems*, the authors set out a reasoned analysis of the market. While the conclusion is reproduced below, the original paper should be read in full. *The Economics of Buying Complex Weapon Systems* concludes:

> The complex weapons acquisition process is afflicted by almost all of the pathologies that prevent efficient outcomes: information asymmetry, conflicting goals, non-commensurable objectives, lack of credible commitments, within government incentive problems, all superimposed with a high degree of technical complexity and uncertainty. Developing a proper diagnosis of the reasons for the necessary imperfections associated with purchasing complex weapons systems is important, as it can help us to understand both the limits and the potential of reform proposals.

> Several lessons can be drawn from the discussion above. Firstly, competition (either ‘in the market’ or ‘for the market’) and fixed-price contracts are useful tools but they will not result, by themselves, in efficient outcomes. Secondly, there seems to be scope for hybrid contracts, involving both cost-plus and fixed-price elements. One of the most important lessons arising from the economics of designing auctions and tender processes is that the details matter. This suggests that ‘one-size-fits-all’ approaches to procuring
complex weapons systems are destined to fail and, instead, the ‘right’ hybrid contract has to be designed on a case-by-case basis. Finally, greater emphasis should be placed on addressing the incentives within government issue – and the financial separation of the DMO from the Department of Defence is a step in the right direction – and on encouraging independent and systematic economic evaluation of the complex weapons acquisition process. (Ergas & Menzies, 2004)

The observation that competition is structurally limited, can inhibit efficiency and is not a panacea for defence procurement invites an examination of different business models. There are also limitations to those other models that promote the use of competition. Different models were discussed in Section 5.5, in respect of the AWD Program. While the alliance industry participants were chosen through competition, the formation of the final acquisition contract was regulated through Phase 2 of the AWD Program, which developed for government consideration two fully-costed capability options (Existing and Evolved Design). The question is whether a hybrid model (same or different) could be used for the future programs arising from the 2009 Defence White Paper?

While the above discussion highlights deficiencies with the competition model in the defence acquisition market, that should not be read as a blanket campaign to move to a closed market. All approaches have their imperfections. A semi-competitive, regulated market has its particular challenges: it requires considerable customer expertise about the business of naval shipbuilding to implement and sustain.
15.1 **Key Themes**

15.1.1 In the face of budget pressures amplified by a global financial crisis, the Australian Government has released its 2009 Defence White Paper. The plan calls for the construction of 48 naval vessels over the next 20 years. Today, the price of warships is rising faster than the rate of inflation. Factors contributing to this rise include the trend towards more capable warships with increasing standards for design features such as survivability and environmental controls. In simple terms, warships are becoming larger and more complicated. In this setting, continued discussion about options and value are important.

15.1.2 Against this demand profile, the naval shipbuilding industry in Australia faces continuing challenges with skills shortages, limited but increasing capacity, and lack of continuity for the different workforce specialties. Good work is being done to correct these problems. One of the other changes in naval shipbuilding in Australia has been the emergence of substantial shipyard-like facilities built by State Governments. This very substantial investment by State Governments will allow new companies to enter the naval shipbuilding market relatively quickly and without the need for their own capital or infrastructure.

15.1.3 The structure and dynamic behaviour of costs to design, build, test, certify and deliver warships is complicated, and the effect of many variations is not as predictable or insignificant as might first appear. While the benefits of equipment commonality are acknowledged in general terms, the concept has gained little traction. While there are many reasons for this, one primary reason appears to be a lack of data, revealing the real magnitude of the cost benefit of a fully realised commonality strategy. The pursuit of better value outcomes means the dynamic behaviour of naval shipbuilding costs (total cost of ownership) deserves more analysis, exploring more widely the interaction between capability, technology and industry choices that have the potential to drive better value outcomes.

15.1.4 Some of the cost drivers that deserve further discussion are warship design and production engineering, build duration and keel intervals, production learning curve efficiency, as well as shipyard productivity and benchmarks. The value of a rolling-build project for one class of ship is to harness the gains that aggregate from the behaviour of these cost drivers. Beyond the production savings is the ability to avoid the non-recurring costs of a second class of warship. These non-recurring costs are growing substantially as warships become more capable and more sophisticated. The full extent of non-recurring costs in a project goes much further than just design. They include certification, builder’s tests and trials, operational test and evaluation, project management, finance, legal and administrative activities, all of which occur through all levels of sub-contractors and suppliers.

15.1.5 Beyond acquisition, there are potentially greater savings to be achieved in the sustainment phase through greater commonality. Entire budgets for duplicated costs in shore infrastructure and integrated logistic support (ILS) services are avoided in support activities such as training, land-based test systems, certification, configuration control, stores management, etc., if one class of warship can replace multiple classes of warship. That is the optimum scenario, but the same sort of savings are accrued if common systems are used in visibly different types of warships and other naval vessels.
15.1.6 One effective method of achieving commonality is the use of a Platform System Engineering Agency (PSEA) in major projects, as opposed to combining the role of shipbuilder and designer, or simply acquiring a functional design for use by the shipbuilder. The role of a PSEA is to create or supply the platform design, engineer the machinery sub-systems, control the configuration, design any modifications required, conduct production engineering in concert with the shipyard, produce production data packages, and manage the engineering aspects of set to work, test and trials, and delivery. As the Design Authority, the PSEA supports certification, verification and validation of the platform system design.

15.1.7 Using a PSEA, optimum savings are achieved when that core expertise is used across different projects, because a common approach to design and engineering results in common systems and ILS solutions. This could also be achieved by using the experienced and proven platform system engineering team of one shipbuilder to service multiple consolidators and programs. Given the benefits of learning from the high density and complexity of the future submarine design and transferring this knowledge into the various warship designs, the PSEA could be developed from the ASC teams engaged in the future submarine design combined with elements of the AWD production design team.

15.1.8 When all non-recurring project costs are summed, then combined with the production efficiencies of rolling-build programs plus the savings achieved in sustainment, acquiring more than one class of warship for similar purposes requires accurate modelling to verify it is the right value solution. There may be solutions where one class of relatively more capable warship can be acquired for the same investment as a fleet of multiple warship classes, each meeting a sub-set of requirements. When the total cost of ownership is considered, there are substantial savings to be had from operating common systems and classes of warship.
16.1 Recommendations

16.1.1 This paper is not the first call for more discussion on improving value in naval shipbuilding in Australia; many people have called for a more expansive and ongoing discussion on the topic. But an enduring discussion has not followed. Too often input is dismissed as simply parochial, and while it frequently is parochial, there has not been the strength in an ongoing discussion to consider such input and unearth the good value propositions.

16.1.2 The following recommendations promote a set of actions that can result in better value in naval shipbuilding in Australia. Some of them are in the interest of South Australia, but they are also of value to the Federal Government and Australia as a nation. Other good ideas will emerge from other sources, with their own interests attached, and they should receive due consideration. But the important matter is to take action and improve the value achieved in naval shipbuilding in Australia today.

16.1.3 The Defence SA Advisory Board recommends:

16.1.3.1 That future Defence acquisition programs are evaluated against total cost of ownership, using qualitative assessment, more thorough benefit-cost quantities analysis, and more dynamic quantitative analysis of different capability-technology/solution-industry options.

16.1.3.2 Equally importantly, that Defence acquisition programs are evaluated in combination, not just in the paradigm of a single program delivering a single capability, in order to realise the substantial savings that can be achieved by avoiding overheads, improving engineering and production effectiveness and efficiency and promoting commonality in integrated logistic support – all to reduce total cost or ownership.

16.1.3.3 That the Commonwealth pursue the ownership of fewer classes of warship and greater equipment commonality, built in greater numbers and preferably rolling-build programs such as can be achieved with the 12 future submarines that the Government announced in the 2009 Defence White Paper.

16.1.3.4 That in the planning of acquisition programs, Defence continues to pursue managed and generally smooth workloads for industry, recognising this applies differently to different elements of the defence workforce such as systems design and engineering, as opposed to production.

16.1.3.5 That the Commonwealth adopts common user facilities for the consolidation of submarines, warships and other naval vessels, while supporting a reasonable but limited number of centres of expertise for hull block fabrication, outfitting and testing. This promotes competition for the ship consolidation role and block fabrication roles, spreading some construction risk whilst maintaining some stability for the local production workers and sub-contractors and suppliers. This approach also permits the use of other business models such as Engineer, Procure, and Construction Management (EPCM), used successfully in the construction industry.
16.1.3.6 That a hub-and-spoke model be used to sustain the expertise required to engineer, sustain (repair, test, train, etc) and upgrade systems capability. This might be structures such as Systems Centres, with nodes in different locations. These centres might focus on a particular mission platform such as the Air Warfare Destroyer, or might be partitioned as a Navy Platform Systems Centre that deals with those sub-systems across multiple classes of warship. There are also benefits to maximising the up-front design detailing to increase module/block outfitting and testing in shipyards.

16.1.3.7 That in the design of future naval programs, a model be adopted that uses a Platform System Engineering Agency in the Tier 1 structure, in order to develop a national body of expertise that will promote systems commonality and provide flexibility for new production business models. New centres of such expertise need to grow to full maturity, they cannot be created overnight, but there should be a strategic plan that reaches beyond current programs. This also could be achieved by using the experienced and proven platform system engineering team of one shipbuilder to service multiple consolidators and programs. Given the benefits of learning from the high density and complexity of the future submarine design and transferring this knowledge into the various warship designs, the PSEA could be developed from the ASC teams engaged in both current and future submarines plus AWD production design.

16.1.3.8 In structuring major acquisition programs, that the Commonwealth in consultation with industry investigate and adopt different approaches to achieve greater cost competitiveness at the Tier 1 level by open book, regulated contracts similar to those currently employed by the United Kingdom.

16.1.3.9 The single naval shipbuilder option, built on ASC and integrating the Platform System Engineering Agency as a division within the shipbuilder, can equally operate under contract arrangements that achieve transparent world’s-best practice, whilst maximising competitive offsite modular construction and subcontracting/procurement – with the real advantage of close integration and feedback of construction and project management experience/outcomes into the design and logistics support/maintenance process. This will arguably deliver the best value for Australia, provided the naval shipbuilder has a top-class board, good governance and experienced and determined management.
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