

The next big grey thing – choosing Australia’s future frigate

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Introduction

The SEA 5000 Future Frigate program has three separate broad objectives. The first is to replace the Anzac-class frigates from the mid-2020s, providing the RAN with a new class of warship with the desired capabilities. The second is industrial: faced with a steady loss of shipyard jobs over the past few years, the Australian Government wants work at the ASC Shipyard in South Australia to begin early in the 2020s. The third objective is to set up a continuous shipbuilding program that will continue to deliver locally built vessels in perpetuity, with an eye to being able to export systems, components or perhaps even warships in the future.

There’s a tension between the first two objectives. The selection of a hull design hasn’t yet been made, although a decision is due in the near future. But it won’t be a matter of getting straight to work on the build—or at least it shouldn’t be. A large body of historical project performance data shows that beginning construction before the detailed design



The Australian white ensign flying on HMAS Parramatta. © Image courtesy Australian Department of Defence

is largely locked down can result in costly and time-consuming problems down the track. And that includes the production engineering (or 'productionising', if we must)—the translation of a design into shipyard practices and processes, which is a complex discipline in its own right. And redesign and engineering work will be needed regardless of the selected design, both to accommodate the government's choice of radar and combat system (decisions announced in late 2017) and for any work needed to meet Australia's regulatory requirements.

At first blush, it might seem that the objective of developing a long-term shipbuilding industry is the least critical thing to worry about in the short term—but that would be a mistake. Decisions made in 2018 will in many ways lock in an effective monopoly on local warship design and construction, as well as determining the likely success or failure of Australian firms in exporting systems or components internationally. Such success would provide a much better chance of Australian industry being more sustainable and local naval shipbuilding being more cost-effective in the long run. Clarity on intellectual property rights and paths to participate in the winning bidder's international supply chains are critical elements of any contractual arrangement. Those need to be agreed upon before contract signature—that is, while the Australian Government retains maximum leverage. Historically, such negotiations are difficult, and some tenderers prefer to leave issues to be resolved later in projects, but that shifts the negotiating leverage to the successful contractor, to the government's net loss.

Similarly, setting up an effective regulatory environment to avoid the extraction of monopoly rents and to drive shipyard efficiency is a necessary step if local shipbuilding is not to be a long-term drain on taxpayers and the wider manufacturing economy. The [RAND Corporation's analysis](#) showed that, to provide value for money, continuous shipbuilding needed to markedly reduce the 30–40% price premium for building in Australia through major industrial reforms and increased productivity. And that was a substantial underestimate if the more than nine billion price tag for three Hobart-class air warfare destroyers (AWDs) is any indication. ASPI has covered that topic extensively in previous publications, and will return to it in the future.

The Australian Government has substantial leverage with all three of the tenderers, given that the \$35-billion nine-ship frigate program is one of the largest open to Western naval shipbuilders. The RAN's fleet of nine is larger than the projected eight frigates being built for the Royal Navy under the UK's Type 26 Program. Italy has ordered 10 FREMM frigates in total (six general purpose and four ASW optimised), and Spain has five F-100 class frigates.

And there are potential synergies with other competitions being run elsewhere. The designs bid for Australia's competition from Navantia and Fincantieri are also short-listed for the [US Navy's 20-ship FFX frigate program](#). BAE Systems' Type 26 wasn't submitted because, not yet having a vessel in operation, it wasn't a proven design—one of the criteria the US Navy specified. Navantia and BAE Systems have offered their frigate designs in their tenders for [the Canadian Government's 15-ship frigate program](#). They will [compete with](#) a consortium offering a Dutch design, and a decision is expected sometime in 2018. Navantia's Canadian bid is based on Australia's Hobart-class AWDs and includes Australia's CEA radar with a Saab Australia interface. BAE Systems will include the CEA radar as a mandated part of its bid in Australia, but is offering Canada a different radar system as part of its Canadian bid.

The multiple competitions being run by Five Eyes partners open up the possibility of global economies of scale and partner navies operating vessels with significant commonality. Being the first of the countries to make a choice means that Australia doesn't have the benefit of knowing which designs the Canadians and Americans will choose. But, conversely, the bidders in Australia's competition will also be trying to use their success to leverage the other competitions, which gives the Australian Government the opportunity to extract favourable concessions on intellectual property and other industrial arrangements.

The requirement

A number of public statements from the government, including the *2016 Defence White Paper*, have referred to a requirement for the future frigates to be antisubmarine warfare (ASW) specialists. However, there are several reasons to think that the preferred solution will be chosen for its ability to perform a broad range of roles. First, the frigates will constitute 75% of the RAN's surface combatant force, and there are many tasks other than those requiring an ASW specialisation. Strict optimisation for ASW would have an opportunity cost for other roles that the Navy probably won't want to incur. Second, the frigates are being fitted with a substantial air defence capability, based on the locally designed and built CEAFAAR radar and a combat system architecture that includes the US Navy's Aegis combat system. Third, there's an increasing recognition within government of the desirability of a capability to defend against ballistic missiles. When announcing the preferred suppliers of the combat system, the [Prime Minister](#) stressed the capability of being able to defend not only the fleet but the entire country against long-range missiles.

As a result, we think that the future frigates will be more accurately characterised as general purpose frigates with advanced ASW capabilities. We look at the three contenders with that description in mind.

The contenders

We summarise the attributes of the three bids below. We focus not just on capability, but also on project risk and the industrial opportunities that might follow. The extent to which the latter might play into decision-making shouldn't be underestimated. Australia's experience with the Hobart-class AWDs has demonstrated the potential for complications to emerge when initiating the local construction of a foreign design. Substantial rework was required on early locally produced modules built from Navantia's design. Similarly, meeting Australian regulatory requirements required many changes. And while there was a notable improvement in shipyard efficiency in the production of vessel 2, and further improvement for number 3, significant cost and schedule penalties had already been incurred. Given the long-term goal of establishing a vibrant local naval shipbuilding industry, the government will be keen to avoid embarrassing setbacks in the early years of the new project. The early travails of the AWD project were the focus of much study (including a [major study by the Australian National Audit Office](#)), and the future frigate program has been structured in a way that it's hoped will take advantage of that hard-won experience.

But even though the approach to SEA 5000 has incorporated lessons learned from the AWD program, there are still likely to be complex program issues to be managed. The SEA 5000 approach of requiring the winning bidder to be the prime contractor managing the build contrasts to the situation in the AWD program, in which Navantia was excluded from the original alliance framework set up to manage the project. The government has now concluded that it's essential for the ship designer-builder to have a lead role in the program from beginning to end.

However, that leads to the possibility that the primes might choose to either team with established Australian shipbuilders ([ASC](#), [Austal](#), or both) or to build their own workforces and develop Australian subsidiaries as capable firms in their own right, perhaps by recruiting from existing firms. Without access to the tenderers' proposals, we can't assess the likely industrial strategies, although the potential outcomes of the recent offshore patrol vessel program might offer a guide. In that case, there was a clear tension between the best capability and design on offer and the government's preferred involvement of incumbent Australian firms.

From the government's perspective, the simplest approach to SEA 5000 would be for the tenderers to integrate existing Australian firms into their proposals. That would probably require the bidding primes to outline plans for developing design and construction expertise within those firms to enable them to compete internationally in the future. That would only be a rational approach for Navantia, BAE Systems or Fincantieri if it resulted in the bidder establishing an export arm or partner in Australia—rather than helping to develop a direct competitor here.

Navantia: F-5000



Source: Navantia Australia.

The Spanish shipbuilder Navantia is offering a design based on the Hobart-class AWDs, which are in turn an evolution of the F-100/Alvaro de Bazan class of frigates, the first of which was commissioned into the Spanish Navy in 2002. The RAN's three AWDs are currently being delivered and commissioned. Eight F-100s built by Navantia are in service with the Spanish and Dutch navies. Navantia also [builds commercial ships](#) and is diversifying into wind turbines and other engineering areas. It's also building the two new auxiliary oiler and replenishment ships ordered by the Australian Government in its Spanish facilities. Thus, the company has a large existing supply chain into which Australian industry could feed, subject to negotiation. Navantia's Hobart-class design is one of five designs short-listed for the US Navy's new 20-ship FFX frigate program, as is Fincantieri's FREMM (see below).

The Hobart class is a multi-purpose surface combatant with strong air defence and ASW capabilities as part of its design. Its sensor suite includes bow and towed-array sonars. Given its multipurpose design brief, it's likely that acoustic signature reduction was a lower priority than would be the case for a purpose-built ASW vessel, although no modern warship is designed without regard for radiated noise. For example, unlike the other two contenders, the F-100 family doesn't have an electric drive, which is an important element in acoustic signature reduction for ASW missions. We understand that the Navantia design could be modified to include an electric drive if required by the government. As with all engineering changes, there would be associated costs and risks. That said, the government has presumably specified acoustic performance requirements, and the important thing for any contender is meeting those specifications.

Like the Spanish Navy's ships, Australia's Hobart-class vessels employ several systems found on all US Navy destroyers: the Aegis combat management system, a SPY-1D air search radar and a Mark 41 vertical launch system (VLS), although the larger US Navy vessels have more launch cells. The AWDs also feature a hangar with enough space for a single MH-60R Seahawk ASW helicopter, which is also a US Navy platform. The Aegis system is government-mandated for the Australian competition, and integrating it into the Fincantieri FREMM or the BAE Systems Type 26 for the first time may require significant modifications.

A future frigate based on the Hobart class would nonetheless require modifications to the AWD design. At the very least, the radar mast will have to be modified for the mandatory Australian-designed and -built CEAFAR and CEAMOUNT active phased-array radar systems. Advice from Navantia suggests that the design could also be modified to accommodate a bigger hangar space that's wide

enough for two Seahawks. That would be a smart thing to do, given the benefit to ASW capability that derives from having two embarked helicopters (see the appendix to this report). It would reduce the commonality with the existing Hobart-class design but, since hangars are part of the superstructure, it should still be possible to maintain significant commonality with the bulk of the modules constructed for the AWDs. The vessel's acoustic signature is more important in an ASW role than in a dedicated air defence role, and it's likely that Navantia will be looking to make some modifications to the Hobart-class design, such as mechanically isolating internal systems to prevent vibration from being radiated from the hull.

On the air-defence and strike weapons side, the 48-cell strike-length VLS is the most capacious and versatile missile magazine among the three design contenders. As a US Navy system, the Mark 41 VLS is compatible with the entire existing RAN missile inventory, as well as other VLS-compatible US Navy weapons, including the Tomahawk cruise missile and SM-3 anti-ballistic missile. The Hobart-class vessels also include deck-mounted Harpoon anti-ship missile launchers. While the Hobart-class VLS may initially be equipped only with anti-air missiles (ESSM and SM-2), the future frigate will be able to carry a more varied range of weapons.

By the time construction of the future frigate begins, ASC will have delivered all three Hobart-class AWDs to the RAN. There would be benefits in continuing to build variants of the same design. For a start, the workforce has a body of hard-earned knowledge of Navantia's design and construction philosophy that would readily transfer across, which would help keep construction costs lower. (Although the greater the modifications required for SEA 5000 from the Hobart-class design, the lower we would expect the savings to be.) The Navantia bid offers the greatest level of continuity of the three. That's a significant advantage from the viewpoint of project management. The early days of the AWD project starkly illustrated many of the issues that can be faced when starting work on an unfamiliar design. That said, if Navantia is successful it will be building the frigates in a new yard at Osborne, so the design will still need to be productionised for those new shipbuilding facilities.

Maintenance and spare parts benefit from the same principle: more commonality of parts and systems between different classes of vessels makes supply chains more sustainable and economical. Successive Chiefs of Navy have publicly noted the desirability of reducing the number of supply chains across the fleet through commonality. In that context, we note that the Navantia-designed Hobart-class AWDs will take their place in the fleet alongside the Navantia-designed landing helicopter docks (LHDs) and afloat support vessels. Also, most of the detailed design work for such things as electrical cabling and subsystems (no small task) should already be completed to Australian requirements and safety standards. Those requirements had a significant impact on the AWD schedule.

Summary: The Navantia vessel is almost certainly the least risky of the three contenders from a project risk perspective, in the sense of Navantia being able to start work relatively quickly. Its baseline design has more missile cells than either of the other contenders, and the Hobart-class AWD starting point brings with it the Aegis combat system and US Navy weapons from the start, unlike the other designs. The Hobart-class pedigree means it's a multipurpose combatant with ASW capabilities, rather than a design optimised from the start for ASW as its primary mission. Navantia Australia already has some 150 employees working in the shipbuilding and design domain, so winning the SEA 5000 contract would build on that foundation. There would be greater commonality with the RAN's existing fleet than with the other options, and the potential for Australian industry to feed into Navantia's global supply chain.

BAE Systems: Global Combat Ship–Australia (Type 26)



Source: BAE Systems Australia.

BAE Systems is a broad-based [global defence and technology company](#) with some 83,000 employees, including over 3,500 in Australia, more than 1,000 of whom are currently working on maritime programs for the ADF. Its shipbuilding business is focused on military construction, the centrepiece being the UK's aircraft carrier (two vessels) and Type 26 frigate programs. BAE Systems is also building the Royal Navy's next generation of ballistic missile submarines.

Three Type 26 vessels are [contracted](#) for the Royal Navy, and a total of eight is planned. Further Type 26 orders are possible, notably subject to the outcome of the current Canadian frigate program. A contract between BAE Systems and the UK Government for construction of the first three has been signed, within a framework contract for the planned total of eight vessels, and construction has begun in BAE Systems' yard on the River Clyde. As such, it's the least proven of the three contenders' designs, being the only one yet to be built and tested—which resulted in it being the only one of the three contenders not to be offered for the US Navy's frigate program. The newness of the Type 26 design is a two-edged sword: it's the most modern design, but the fact that it hasn't yet been translated into hardware means that evaluation of its performance must perforce be based on projections—which should necessarily be regarded with some scepticism, presumably reflected by wider error bars in the Australian Government's evaluation matrix. However, the UK program is some five years ahead of the SEA 5000 program, given that construction started in 2017. BAE Systems argues that all of the testing and development work on the Type 26 will have been completed by the UK, so there will be minimal design risk for Australia. The first of class UK Type 26 vessel is not due to be accepted by the UK Ministry of Defence until 2025, with operational acceptance into the [Royal Navy planned for 2027](#). With some supply-chain contracts already in place and a continuing construction program in the UK, there will be a live supply chain for Australia to use and to have Australian firms join, and the extent of that is likely to be a significant point of negotiation.

The Type 26 was designed from the outset to be an ASW specialist incorporating new acoustic technologies and design principles. The Royal Navy variant of the Type 26 will employ a combined diesel–electric or gas engine configuration, along with electric motors for propulsion. That means that the vessel can be driven either by a single gas turbine (via direct drive) or by using the combined electrical output of four 3-megawatt diesel generators to power the electric motors. The generators will be mounted

inside acoustic enclosures to reduce the transmission of noise from the ship into the water. The electric propulsion system provides a very low underwater radiated noise signature, whereas the gas turbine offers a higher power option for when speed is more useful than stealth.

The Type 26, as configured for the Royal Navy, features a 24-cell 'strike-length' Mark 41 system, as well as 48 shorter CAMM VLS cells, each of which can house a single Sea Ceptor missile, which is a short-to-medium range air defence missile analogous to the ESSM on all of the RAN's surface combatants. Both the ESSM and the Sea Ceptor can be 'quadpacked' into a single Mark 41 cell. For example, an AWD with 48 VLS cells can carry 48 ESSMs in 12 cells and still have 36 free for other weapons. With a lower capacity 24-cell VLS on the Royal Navy's Type 26, quadpacking becomes relatively more important. Of course, the missile load-out of a vessel takes up space and weight that potentially displace other systems, and different choices will typically be made for air warfare or ASW dedicated vessels. If required, significantly more Mark 41 VLS cells could be added to an Australian design, although that would require modifications to the extant design and so add an element of risk.

The radar mast on an Australian variant would be substantially different from the Royal Navy's design to accommodate the government-mandated CEAFAAR active electronically scanned array radar instead of the UK's Artisan 997 mechanically scanned radar. The CEAFAAR radar is state of the art and almost certainly offers a substantially higher performance than the British system, and electronically scanned radars have a responsiveness not possible from mechanically rotating radar systems. BAE Systems advises that the Type 26 has significant power, weight and other service margins, enabling the upgraded combat systems to be incorporated without having to make major changes to the other ship systems.

Uniquely among the three contenders, the Type 26 has a large mission bay amidships that can house and deploy a wide range of payloads, including unmanned aerial, surface and subsurface systems, small boats and supplies, or a second Seahawk helicopter for dedicated ASW operations—although the arrangement would involve significantly more handling of the helicopters than with two dedicated hangars. The mission bay makes the vessel suitable for the wide range of tasks that RAN surface combatants are routinely called upon to perform and provides flexibility for mission loads to change through life.

The Type 26 has no commonality with the AWD design, meaning that there would be a substantial learning curve for production engineering and construction compared to the Navantia design. And the skills needed to build many of the advanced features incorporated in its design will take time to acquire in the Adelaide yards.

As the name suggests, the 'global combat ship' was designed with exports in mind: Canada is also considering the Type 26 as an option for its own future surface combatant. Canadian requirements are very similar to Australia's, and the choice of the same basic ship design by the UK, Canada and Australia could result in 32 or more similar warships being built. (Given Navantia's bid in both competitions, there's also potential for Australia-Canada cooperation if both countries select the Spanish design.) Combined UK, Australian and Canadian orders would result in a large overall production run, and a mutually beneficial three-way industrial arrangement may be possible—although the benefits of commonality would be reduced by the substantially different onboard systems (combat systems, VLS, weapons and radar) that the British and Australian ships will have. As well, the politics of naval shipbuilding in each country will work against a coordinated set of decisions (such as arrangements for components for all three navies being manufactured in one country), making it unlikely that all the possible efficiencies could be harvested.

Despite that, a potential opportunity exists for Australian industry to enter a global supply chain that will build and sustain 32 ships. Australian businesses are already supplying components for Batch 1 of the UK Type 26 program, and more are expected to support construction and equipment manufacture for Batch 2.

Summary: There's a lot to like about the capability promised by the Type 26, and it's the most modern design in the competition. It has several attractive ASW features as well as a multipurpose mission bay that will enable rapid configuration for other tasks. The downside is that its capabilities aren't yet proven. The supply-chain opportunities with the BAE Systems bid relate closely to its success in further Type 26 sales as well as to additional successful negotiations to gain access for Australian suppliers into the UK's Type 26 program.

Fincantieri: FREMM-IT-ASW



Source: Patrick Durrant, 'Fincantieri stakes its claim for Sea 2000, *ADM: Australian Defence Magazine*, 19 December 2016, [online](#).

Fincantieri is a very capable global ship designer and builder, with experience building [commercial and military ships in multiple nations](#). Some 60% of its workforce of around 20,000 are outside Italy, including in the US and Asia. As a result, its global supply chain is large, providing probably the greatest opportunities for Australian industry to contribute to a global commercial and military market as an export partner. The company's FREMM vessel has been short-listed by the US Navy for its frigate program. But, as noted above, a combined Naval Group / Fincantieri unsolicited bid to build FREMMs for Canada was rejected by the Canadian Government [in December 2017](#), despite the companies offering a fixed-price, together with technology transfer to Canadian firms so that they could be involved in future FREMM sales in the international market. Consequently, the size of the global FREMM fleet will largely depend on the outcomes of the Australian and US Navy competitions.

The FREMM 'European multi-purpose frigate' was a joint development between France's DCNS (now Naval Group) and Italy's Fincantieri to produce four different frigate variants on a single hull design. The first FREMM vessels were commissioned by the French Navy in 2012, making it a relatively new but proven design. Fincantieri's future frigate proposal is based on the Italian ASW variant, which—significantly for an ASW role—features a double hangar and combined diesel–electric and gas engine configuration.

The double hangar is a major selling point on the FREMM, if Australia really is seeking ASW-optimised vessels able to operate alone as well as in a task group in which other vessels might have embarked aircraft. As shown in the appendix to this paper, being able to employ two Seahawk ASW helicopters—or some combination of rotary-wing platforms, manned or unmanned—is a substantial force multiplier for stand-alone ASW operations. Like the Type 26, the FREMM can turn off its gas turbine to reduce noise during ASW operations, but it can also employ its gas turbine and diesel generators simultaneously.

In terms of armament, the Italian FREMM features a 16-cell SYLVER VLS and eight deck-mounted Otomat anti-ship missile launchers, but space is reserved for up to 16 additional VLS cells, bringing the total to 32 (which is the number on the French FREMM). The SYLVER VLS is designed for the Aster anti-air missiles and Storm Shadow cruise missiles used by France, Italy and the UK. An Australian variant would be likely to feature a Mark 41 VLS (also 32 cells) instead, to be able to use existing missile inventory and to incorporate the cooperative engagement capability that would allow the pooling of missile resources with the US Navy in joint operations.

Relative to the Type 26, the FREMM offers the advantage of already being in service, and thus being more readily evaluated. For example, its acoustic signature can be measured, rather than being a projected figure.

In terms of project risk, there's the potential difficulty of working with a new designer that's unfamiliar with the Australian shipbuilding environment. And the benefits of a vessel already in service are partially offset by the fact that practically none of the Italian FREMM's major sensor and weapon systems—VLS, radar, CMS and possibly sonar—would be preferred for an Australian design.

Summary: The net result is that the main attractions of the Fincantieri design are its hangar capacity, its relatively new design and its ASW-specific systems. On balance, it's well suited to the ASW-specialist role promulgated in the Defence White Paper. There's considerable scope on the industrial side from Fincantieri's substantial global fleet of both military and commercial vessels, opening up the possibility of Australian firms contributing to a broad global supply chain.

Summary

From what ASPI sees in open source information and in extensive unclassified discussions, the discriminators appear to be as follows:

- **ASW performance:** It remains to be seen exactly how important ASW specialisation is, but both the Fincantieri and the BAE Systems designs seem to have an edge over Navantia's. BAE has the advantage of the most modern design with advanced quietening techniques designed in, while Fincantieri also offers acoustic reduction measures and can provide for hangars for two ASW helicopters from its baseline design. (In the case of BAE, the judgement on capability relies on confidence in the design, not measured performance of a ship in the water).
- **Project risk:** Navantia has the advantages of workforce experience from the Hobart-class AWD program and having lived the lessons from that program, as well as already having integrated the Aegis combat system into the design. The shipyard advantages are lessened, however, by the fact that the future frigates will be built in a new facility and by the recent rundown of the AWD workforce.
- **Industrial strategy:** Fincantieri has the broadest market and supply chains because it builds both commercial and military ships for the global market, but the extent of Australian access to that global supply chain will depend on the details of the tender and the government's ability to negotiate. Navantia's military supply chain has commonality with the RAN's Hobart-class, amphibious and at-sea replenishment ships. The scale of BAE's program is still being defined. (It's possible, of course, that either of these firms could be offering better intellectual property rights and more compelling supply-chain involvement in their bids, which would change the assessment.)
- **Cost:** The Navantia design will probably be the most efficient to implement in Australia's shipyards due to commonality with the AWD and is likely to be the least expensive option, unless significant design changes to achieve high-performance ASW requirements are imposed. The advanced capabilities and design of the Type 26 probably make it the most risky to start on here, and possibly the most expensive.

At the risk of oversimplifying a complex situation, tables 1 and 2 below summarise the pros and cons of the three vessels.

Table 1: Summary of the characteristics of the three future frigate competitors.

	Proven design	Commonality with AWDs	ASW helicopters	Strike-length VLS cells	Electric drive	Multipurpose mission bay	Likely cost ^a
BAE Systems Type 26	No	No	1 ^b	24	Yes	Yes	Highest
Fincantieri FREMM	Yes	No	2	32	Yes	No	Intermediate
Navantia F-5000	Yes	Yes	1 (2 as option) ^c	48	No ^d	No	Lowest

a Our assessment, based on open-source information.

b The Type 26 can accommodate a second ASW helicopter in its mission bay, but routine two-helicopter operations would require additional handling.

c The Navantia design could be modified to include hangar space for a second helicopter if required.

d The Navantia design could be modified to include electric drive if required.

Table 2: Industry opportunities

	Fleet of similar vessels	Global supply chain
BAE Systems	Ordered for the Royal Navy. Possible sale to Canada.	Depending on Type 26 sales, could open up UK–Australia (and possibly Canada) collaboration opportunities.
Fincantieri	In service with several NATO countries. On US Navy short list.	There's a large commercial fleet of Fincantieri-designed vessels, as well as warships, providing opportunities beyond just the frigates.
Navantia	Similar to the RAN's own Hobart-class AWDs. F-100 derivatives in service with several NATO countries. In Canadian competition and on US Navy short list.	If this bid is selected, Australia would be operating four different Navantia-designed vessels, which provides opportunity to get into the broader global supply chain.

Conclusion

As is almost always the case in the acquisition of complex defence systems, the Australian Government will be weighing the competing factors of future capability, cost and project risk. It's always hard to predict the results of such competitions. There have been past instances in which the government made choices different from the preferences advanced by Defence; for example, the recent future submarine decision surprised many external observers. And, as the overly convoluted industrial strategy surrounding the recent [offshore patrol vessel](#) seems to show, the state-based politics of shipbuilding can distort rational decision-making. Much will depend on exactly which factors the National Security Committee of Cabinet weighs most highly, including the industrial strategies available, along with which of the three bidders offers the clearest access to broader supply-chain opportunities for Australian firms as a result of this \$35 billion project.

Without access to the detailed tender responses and Defence's evaluation of them, it's difficult to make a precise judgement about the weights to be applied to capability, project risk and industrial opportunities (although it might be possible to divine them from the government's stated rationale when it announces its decision).

But we can say with confidence that in the case of the frigate program a large weight has to be given to the industrial strategies available to Australia. The focus will be not just on frigate production here, but also on participation in the successful bidder's wider production and maintenance chains across its business lines and around the world. Being able to access those market opportunities is a necessary condition for developing a successful naval shipbuilding industry in Australia that doesn't incur substantial premiums compared to offshore sourcing. Australian firms being export partners with the winning company also provides the best opportunity for future export success—although that's far from guaranteed. To help reach those goals, intellectual property rights that allow Australian firms to gain technology transfer and then use that technology to export into the designer-builders' own supply chains, and perhaps even independently, will need to be negotiated before contracts are signed.

The government will also have to make a judgement about the promised capability of the offering from BAE Systems compared to the ships already in the water from the other competitors—with the added complication of substantial modifications of differing degrees being required whichever design is chosen. And, given how heavily Australian naval shipbuilding has been politicised in recent years, it's always possible that Defence's preferred choice will face some competition at the cabinet table due to the proximity of the next federal election.

Appendix: the arcane art of antisubmarine warfare

Andrew Davies and James Mugg

Submarines have played an important role in naval warfare since World War I, and for good reason. They're difficult to counter, and even the possibility of their presence in an area of operations can tie up a disproportionate amount of an adversary's resources. The enormity of the ocean makes it one of the few remaining areas on Earth where big military platforms, such as ballistic missile submarines, can hide. Despite the development of new detection technologies, the ocean remains mostly opaque at depths of just a few dozen metres. Along with continuing improvements in submarine technology, ASW, as practised by Western navies, remains difficult. In particular, protecting power projection assets such as aircraft carriers and amphibious vessels during expeditionary operations—in which the adversary has the 'home ground' advantage—is extremely challenging.

That combination of factors makes submarines a very attractive acquisition for states that can afford to buy or build them, especially those that seek to blunt the advantages of Western navies. And, since Indo-Pacific and Asia-Pacific economies have been growing quickly in recent decades, the number of states that can afford to operate modern submarines has increased dramatically. China alone will have 70 submarines in the Asia-Pacific in 2020, and those boats will contest the underwater space with a similar number from a dozen other nations. The capability of the submarines in the area is also increasing—China, Russia, the US and perhaps India will be operating nuclear submarines in the Asia-Pacific region in years to come.

Those observations have driven a lot of the thinking behind the future frigates project. The high-level description for the future frigates in the *2016 Defence White Paper* (and reiterated in the 2017 National Shipbuilding Plan) says that they'll be 'optimised for anti-submarine warfare'. For reasons explained in body of this report, we're not entirely convinced that ASW will dictate decision-making to the extent that the word 'optimised' would suggest. And that probably isn't unreasonable for a navy the size of the RAN—as is usually the case, a high degree of specialisation would come at an opportunity cost to other capabilities, drive up the cost significantly, or both. We think that there's scope for the RAN to take an approach to ASW based on smaller, cheaper and more numerous platforms, but that's largely a separate discussion from the SEA 5000 focus of this paper.

Given the Navy's wide range of operational tasks, it's not clear to us that it would see itself as being well served by having nine of its 12 surface combatants being highly specialised. Trade-offs are going to be necessary, even though ASW is likely to be an increasingly important task in the light of regional trends.

In this appendix, we analyse how surface combatants fit into the picture of modern ASW, and how they might work with other ADF and allied force elements to produce an effective ASW capability. It's not a complete primer on ASW, but it focuses on the factors that might allow decision-makers to discriminate between competing surface vessel designs.

What is antisubmarine warfare?

ASW should be understood as a system of capabilities designed to defeat an adversary submarine's mission goals of collecting intelligence, launching strikes against naval or land targets or denying the use of the sea. ASW is an umbrella term for a broad set of missions, concepts and capabilities. A surface combatant's contribution to ASW is not as simple as a ship and a submarine going at it one on one. Instead, it's one element of a network of capabilities; any platform or sensor that can contribute to detecting, identifying, tracking or destroying an adversary submarine could be considered an ASW capability. For example, a satellite that provides images that show that an adversary's submarine is in port could be considered an ASW capability.

Other examples of ASW operations could include:

- defending against a submarine's weapons once they're fired (given the difficulty of ASW, this eventuality should always be a high priority rather than an afterthought)

- tracking an adversary submarine from the time it leaves port, using any combination of intelligence, submarines, surface vessels and aircraft
- locating an adversary submarine and, if required, destroying it
- using ASW sensors to rule out, with a high degree of confidence, the presence of adversary submarines in an area ahead of a naval task group to ensure safe passage.

ASW sensors

Above the water, sensors that operate by electromagnetic radiation (visual light, infrared and radio waves) are dominant. But electromagnetic waves at those wavelengths don't propagate very far in seawater. That's why the ocean becomes 'twilight' dark at depths of just 200 metres. Radio waves are absorbed even faster than visible light, so submarine radio transmissions normally take place at periscope depth or via buoys equipped with antennas.

But sound waves propagate well in water, so active and passive underwater acoustic sensors have been extensively used for the detection of submarines since World War II. Similarly, submarines use acoustic sensors to detect ships, other submarines and even aircraft. A combination of a submarine with a good sensor fit and—crucially—experienced sonar operators with the right tools and a creative mindset can generate a remarkably sophisticated picture of the operating environment for many kilometres in every direction.

Passive sonar is essentially a listening device that makes no emissions of its own. All vessels make noise at a range of frequencies, and propulsion systems and flow noise are major contributors. The energy at each frequency emitted by a vessel (its 'acoustic signature') is distinctive. All vessels make noise across a range of frequencies, and propulsion systems, hotel systems, weapon systems and flow noise are each very useful contributors to the overall radiated picture (from the point of view of the ASW forces; for the submarine, they're a threat to its continued existence). With experience, monitoring the dynamic signature of a manoeuvring submarine provides cues for the detection, classification (type of submarine), localisation and even assessment of command intent and myriad other tactical indicators.

However, the ocean is getting steadily noisier. Background noise levels have doubled every decade over the past 50 years, including in frequency bands of ASW interest. One of the reasons is the greatly increased volume of shipping, including very large vessels that radiate a lot of noise at low frequencies, which propagates over long distances. Another interesting and happy reason is the resurgence of whales, which fill the ocean with a cacophonous long-range noise (as well as generating passive and active sonar contacts). Deep-sea oil exploration also contributes to the overall noise level.

Submarines have quietened by a similar amount over that same 50-year period, meaning that the difference between submarine-generated and background noise signals has changed by a factor of 1,000. One implication of that observation is that the utility of direct passive listening for noisy submarines has steadily diminished and in most operational circumstances is essentially useless. A recent [NATO report](#) observed that 'modern submarines, both nuclear and diesel, provide passive detection ranges better characterised as hundreds of yards rather than multiple miles'.

The report says that during the Cold War, given a rough indication of a submarine's position, a group of helicopters, maritime patrol aircraft, or both could sow dozens of passive buoys over hundreds of square kilometres and, theoretically, have a good chance of making contact on the first mission. Today, the area that can be covered by the same number of helicopter launches and deployed buoys has shrunk considerably, to the point that getting enough aircraft into the area for sufficient passive coverage is unlikely. The net result is that passive detection can't be the sole tool of choice for modern ASW practitioners.

That said, passive sonar isn't entirely outmoded. It has the advantage of not flagging the position of the ASW forces, and a submarine commander who thinks that passive detection is a possibility will face constraints on any activities that generate

significant amounts of sound, including running at high speed or running diesel engines to recharge the batteries in conventional boats. And there are some interesting possibilities in using the background sound, including biological noises, of the ocean as the source for sonar detection—either by looking for reflections of background noise of a submarine, or even by listening for the noise of marine animals disturbed by the passage of a boat.

Nonetheless, passive sonar will often be inadequate and there'll need to be a much greater focus on other techniques, including **active sonar**. The basic idea is that the active system puts acoustic energy into the water (the loud 'ping' beloved in submarine movies) and that energy reflects off solid objects and returns to detectors, giving the bearing of the contact and, through timing, the distance.

To reduce the probability of detection by active sonar, a submarine has few options. Being a large metal object, it's highly susceptible to detection. Modern submarines have a coating of 'anechoic tiles' that absorb sound energy to reduce the return a submarine gives off when exposed to active sonar emanations, but the return can't be eliminated. The larger the submarine, the larger the reflected signal will be, which means that small conventional boats will often be harder to detect than large ones such as nuclear submarines—or the future submarines that Australia's planning to build.

But active sonar isn't a panacea for ASW forces, as an active source is highly audible to the submarine ('counter detection'). Switching on a flashlight in the dark allows the user to see better, but it also makes the location of the flashlight obvious. Sound spreads as it travels, reducing the intensity of the signal, so a submarine will almost always detect the one-way active transmissions of an approaching vessel before the operator on the ASW platform will be able to detect the submarine from the much weaker two-way reflected signals. Depending on the 'range of the day', which is highly environment-dependent, the submarine may be able to safely manoeuvre to weapons release range before it can be detected. For that reason, active sonar isn't generally the sensor of choice for surface vessels—given the range of today's submarine-launched weapons, it's questionable whether they're worth fitting. Instead, the sound sources should preferably come from elsewhere. Using embarked aircraft that can deploy active sonar sources is one way of decoupling the source of active emanations from the position of the surface vessel (limited by the range of the aircraft).

Naval helicopters are a staple of modern ASW because they can spread sonobuoys over a large area in the vicinity of the surface vessels they're operating from in relatively little time. (Sonobuoys are small, deployable, expendable devices that incorporate active and/or passive sonar systems and a transponder to relay acoustic data back to the aircraft or other networked force elements.) But helicopter payloads are limited, and carrying weapons significantly reduces the load of buoys, mission endurance, or both. The US Navy is experimenting with a mix of helicopters in which some carry only sensors and others only weapons. That makes good sense, but it also requires the simultaneous availability of multiple helicopters, which is much easier in a fleet with aircraft carriers and very large flat-top amphibious ships than in a frigate-centric navy such as the RAN. As we show below, helicopter availability is potentially a strong discriminator between SEA 5000 contenders.

For wider area coverage, fixed-wing maritime patrol aircraft operating from land bases can lay a sonobuoy field well ahead of a naval task group to help develop an operating picture well before a possible transit. The downside of that model is that the task group must be at sea continuously, while the patrol aircraft will be on station only intermittently.

Some ASW helicopters are also capable of 'dipping' a powerful active sonar source into the water. Because the helicopter can stop and dip anywhere within its mission radius, the submarine doesn't get the same advanced warning as it would from an approaching surface ship. Multiple helicopters operating as a 'dip gang' make a submarine commander's job very difficult, greatly complicating command decision-making. Such an approach also limits the submarine's ability to counter the ASW force. While submarines can carry missiles capable of engaging helicopters, that's a high-risk strategy if there are multiple aircraft present: as soon as a missile broaches the surface, the submarine's position is revealed to any other aircraft in the area.

The submarine's life can be made even more difficult if ASW forces employ **multistatic tactics**. One such technique is to sow a field of passive sonobuoys (which the submarine can't detect unless it hears the splashes as the buoys are dropped) and then use an active dipper to create a source. Any echoes can be picked up not just by the dipping system but by any buoys within range, allowing the submarine's position to be triangulated. Multiple helicopters carrying weapons or additional sensors make it very hard for the submarine to prosecute its mission. Done well, aggressive multistatic active sonar can intimidate submarine crews. The NATO report on airborne ASW puts it this way:

[T]he submarine, should it determine that a multi-static source is being employed, cannot know which direction to turn to avoid the pattern. Multi-statics are still an emerging technology, but, based on analysis of classified briefs made available for this study, may address many of the challenges presented by quiet submarines operating in acoustically challenging operational environments.

Other sensors are also relevant to ASW. **Radar** can be used to detect any projection a submarine makes above the water—such as a snorkel for the intake of air required for running diesel engines ('snorting') in the case of a diesel–electric boat, or any sensor mast. Infrared sensors can pick up the warm wakes of nuclear submarines in shallow water, or the exhausts from snorting conventional submarines. **Magnetic anomaly detectors** detect variations in the Earth's magnetic field that might be caused by a large metallic submarine, although signature-reduction methods such as reducing the volume of ferromagnetic metals in submarines have reduced the usefulness of such detectors in recent decades. The net result is that sonar remains the principal sensor type used for ASW operations.

And no discussion of future ASW would be complete without mentioning the potential of **unmanned systems** to play a significant role. Unmanned aircraft, submersibles and surface craft, whether operating from vessels or otherwise, could significantly augment any network of sensors. Similarly, seabed arrays of acoustic sensors, although far from a new technology, can provide situational awareness across wide areas, form trip-wires across choke-points to cue other platforms, or both. In the discussion below, we analyse the role of large manned ASW helicopters. They will remain important because only large platforms can carry the weapons and sensors (such as low-frequency active sonar) required to detect submarines at long range and engage them. It's entirely possible that unmanned systems will be able to do those things in the future, but payload considerations will necessarily mean that they'll also be large vehicles. Smaller unmanned systems should be thought of as valuable supplements to the force structure, not as replacements for existing capabilities.

ASW weapons

Perhaps surprisingly, there aren't many types of ASW weapon currently in use. Previously useful devices such as depth charges and mortar-like area coverage weapons have largely fallen from favour in Western navies, which base their ASW capability on large surface vessels. Depth charges and the like require the weapons delivery platform to get too close to the submarine to be effective—by which time modern submarine-launched weapons could be brought to bear. Such an approach might be acceptable if the surface vessel is a small and cheap one—especially if it's unmanned—but not if it's a multibillion-dollar platform that represents 10% of the navy's war-fighting capability. As well, closing on a submarine to deliver weapons was a lower risk proposition when submarines relied on 'straight running' torpedos and thus required the right alignment of the competing platforms and the ability to close to short range, but modern guided or autonomous homing torpedoes make that a fraught prospect.

The principal modern ASW weapon is the lightweight homing torpedo. At around 250 kilograms, they're in fact quite large weapons (but 'lightweight' compared to the heavyweight torpedos used by submarines). The size is driven by the need to carry enough fuel to provide a range of up to 10 kilometres and to have a warhead large enough to destroy a submarine. Lightweight torpedoes can be delivered by helicopters, maritime patrol aircraft and surface combatants. The torpedo is launched in the vicinity of a contact that has been assessed to be a hostile submarine and can use a combination of passive and active sonar to locate the submarine for the terminal phase of the engagement.

Australia's current surface combatants carry European MU90 lightweight torpedoes for use in their own launchers, and American Mark 54 torpedoes for use on the embarked MH-60R ASW helicopters. The future frigates may be similarly armed, although there may be a case for rationalising the torpedo fit to a single type. The current arrangement of two different torpedoes, which requires two different logistics chains in support, is the result of the failure of the project intended to fit the ADF's helicopters and maritime patrol aircraft with the MU90. Plans to fit the European weapon onto ADF aircraft were abandoned when integration difficulties proved insurmountable. The ADF's future maritime patrol aircraft, the P-8 Poseidon, will use the same Mark 54 torpedo as the embarked helicopters.

ASW operations

While we think that the time is right for an end-to-end rethink of the ADF's approach to ASW, the main focus of this paper is the role of surface vessels in ASW and the implications for the SEA 5000 decision. Some underlying principles should underpin any surface-combatant-based ASW. The vessel should have:

- the lowest possible acoustic signature, both to minimise the chance of being detected by the submarine's passive sensors and to make the vessel's own sensors more effective by reducing self-noise
- sensors capable of searching the greatest possible sensible volume of water for submarine contacts, with the ability to vary the depth of sensors to allow for water layers and tactical considerations, such as a submarine often being near periscope depth
- offensive systems capable of engaging a hostile submarine
- defensive systems capable of defeating the submarine's weapons
- networking, including tactical data links to other ADF air and maritime platforms.

Not all of those broad requirements are useful discriminators between the contenders for the SEA 5000 contract. All three bidders will be able to offer state-of-the-art sonar systems selected from the Western market, including variable-depth and towed-array sonar systems. The same reasoning applies to torpedo defence and antimissile systems. Similarly, all of them will be able to incorporate advanced communication networks, and all will embark the Navy's next-to-new MH-60R ASW helicopters. So we can practically limit our discussion to the two important factors for which there are significant differences between the contenders: the number and type of embarked aircraft and vessel signature management.

Embarked aircraft and ASW

Distances matter a lot in ASW: detecting a submarine before it's in a position to sink a vessel or strike at a target on the land is far preferable to trying to even the score afterwards. Having eyes and ears over the horizon is important, so the ASW capability of surface combatants is often more about the aircraft they embark than about systems attached to the ships' hulls. ASW is not best practised by big 'lumpy' systems, but instead by disaggregating sensors and terminal effectiveness over a wide area. Aircraft are the most effective way to do that from a surface vessel.

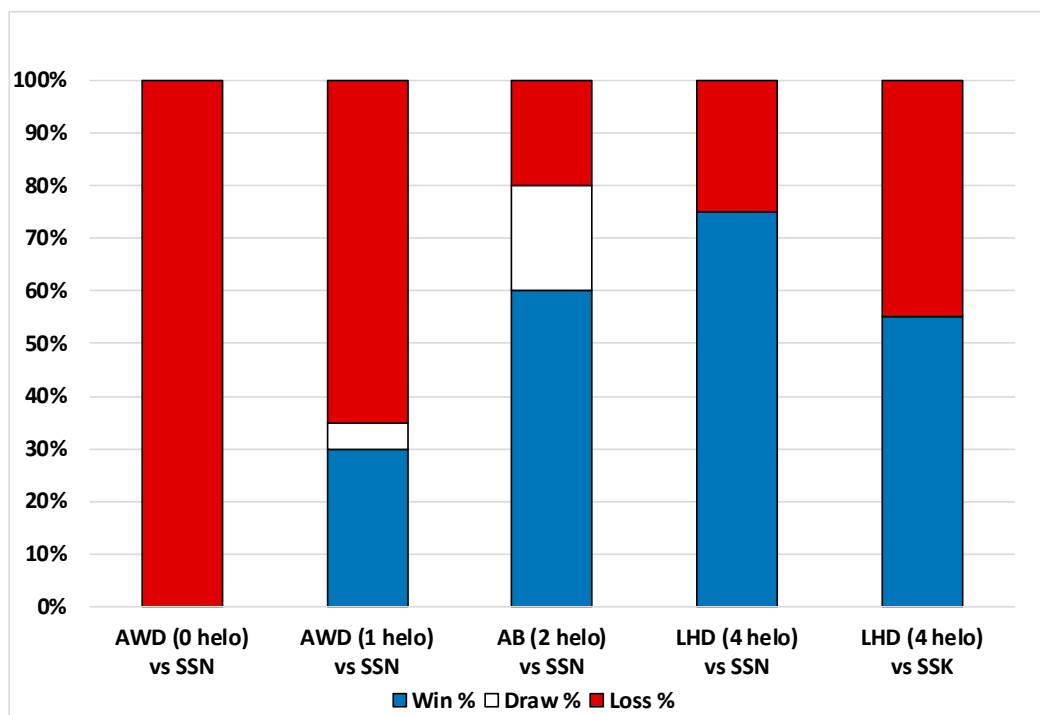
In the (admittedly simplified) discussion here, we examine the role of helicopters embarked on a single surface combatant. Surface combatants often—although certainly not always—operate as part of a task group. In that case, it doesn't matter which vessel ASW helicopters fly from. For example, a task group including a Canberra-class LHD as well as a surface combatant might have a single ASW helicopter on the surface combatant and several more embarked on the LHD. That said, there are scenarios in which a surface combatant might find itself alone in an area in which an adversary submarine might be operating—for example, when escorting a high-value unit such as a tanker laden with aviation fuel—so stand-alone ASW capability is also a valuable asset.

For our investigation of the value of embarked helicopters to the ASW mission, we created some simple ASW scenarios using the 'Command: Modern Air/Naval Operations' computer program. While it's a commercial game product, it has a good pedigree, being based on the 'Harpoon' game developed using NATO ASW doctrine and realistic system parameters. Our simulations weren't meant to be ultra-realistic, as we're interested only in identifying the drivers of ASW effectiveness for comparative purposes. The scenario involves a submarine (red team) and surface vessel (blue team) hunting each other in a 2,000 square nautical mile deepwater arena, with no time limit. All the platforms on each side patrol the mission area at random vectors until they detect an enemy and follow the kill chain through to conclusion. A win for blue is defined as defeating the enemy submarine while remaining afloat. A draw is when both vessels are destroyed, which can happen when an already airborne helicopter torpedoes a submarine after that submarine has destroyed the surface ship. We caution the reader to not believe the calculated numbers—the artificial scenario almost certainly skews the results in favour of the ASW side by boxing the submarine in—but the relativities between the cases are reliable indicators of *relative* efficacy.

The intent of the tests was to investigate the impact of having more helicopters available for an ASW mission, rather than evaluating specific surface platforms. In our model, the blue team embarks zero, one or more MH-60R Seahawk ASW helicopters. The number of helicopters depends on the platform: zero or one Seahawk on an Australian Hobart-class AWD, two Seahawks on a US Navy Arleigh Burke Flight IIA. For comparison, we also included a case of four Seahawks embarked on an Australian Canberra-class LHD. That's entirely unrealistic—an LHD has no shipborne ASW sensors and would never be sent out alone into an area potentially patrolled by a hostile submarine. However, the results are nonetheless illuminating (Figure 1).

The baseline scenario tests an AWD with no embarked helicopter against a US Navy Virginia-class nuclear-powered attack submarine (SSN). Not surprisingly, the AWD loses every time; even when both vessels detect each other, the submarine's Mark 48 heavyweight torpedo has twice the range of the AWD's MU90 lightweight torpedo, so the submarine can always pick the AWD off at a comfortable distance. (In fact, in all test scenarios, antisubmarine kills were always achieved by a helicopter-launched Mark 54 torpedo—raising the question of whether a ship-launched ASW torpedo system is worth the space it occupies.) Attempting ASW with no airborne sensors or long-range weapons is a one-way mission for a surface combatant.

Figure 1: ASW platform performance



The AWD with a single embarked Seahawk has the bare minimum of airborne ASW capability. In our trials with that configuration, the surface vessel wins outright 30% of the time and gets sunk 65% of the time. (In the other 5%, both sides can claim a Pyrrhic victory.) Increasing the number of helicopters dramatically improves the outcome for the blue team: an Arleigh Burke with two Seahawks wins 60% of the time and gets sunk without destroying the submarine in just 20% of trials.

The main difference in the outcomes with one or two helicopters is the length of time for which an aircraft is active. The program models Seahawk sorties at a little under three hours duration, with a turnaround time of about four hours between sorties. That means that the AWD with a single helicopter has a Seahawk in the air just 40% of the time (which probably overstates the practically sustainable sortie rate), while the Arleigh Burke has one in the air closer to 80% of the time. Even when the submarine manages to sneak a kill against the Arleigh Burke, there's usually a Seahawk in the air that can use the ship's final sensor data to even the score.

The LHD with four Seahawks is able to always have at least one in the air, which improves the blue team's outcomes compared to either of the surface combatants. (The results in that case are all either win or loss, because the modelled LHD has no torpedo detection system, which means that the airborne Seahawks can't be cued by the LHD.)

We also ran simulations with a conventional Collins-class submarine instead of a Virginia-class nuclear boat. The Collins was a little harder to detect than the Virginia, which is consistent with conventional wisdom that diesel-electric submarines are smaller (with lower active sonar signature) and tend to be quieter (with lower passive sonar signature) than their nuclear-powered counterparts. However, we note that the simulated fight took place in the oceanic equivalent of a phone booth. In open water, the faster transit speed and better dived endurance of the nuclear submarine would make it a much more formidable opponent.

The conclusion from this modelling is unequivocal (and not at all surprising): a surface vessel with two helicopters is going to be much better at ASW than a ship with only one. And the fact that an LHD, with no organic ASW sensors but with four Seahawks, performs even better than an Arleigh Burke with two helicopters tells us that ASW helicopters are one of the most valuable ASW capabilities you can put on a ship.

But ASW helicopters are necessarily large and complex (and therefore expensive) platforms. Their ability to carry large active dipping sonars and ASW weapons is invaluable, but their maintenance demands and the necessity for flight crews tend to limit their availability. That's where unmanned systems could play a valuable role. Supplementing their high-end ASW capabilities with smaller, less capable airborne systems could be a more cost-effective way to generate wide-area ASW effects. The development of unmanned aerial systems—both rotary-wing and small fixed-wing aircraft—has opened up many possibilities for the future. The ability to deploy a large number of drones, each with only a small payload (perhaps a few sonobuoys or a transponder to monitor an already sown field) could be a significant force multiplier for the larger aircraft. As discussed in the body of this report, the three contenders for SEA 5000 offer different aviation capabilities.

Vessel signatures

There are also potentially significant differences in the signature management of the three contending vessel types. It's advantageous for a surface vessel to put as little sound into the water as possible. That has two operational advantages. First, it reduces the chance of being detected at operationally useful ranges by an adversary submarine. Second, the ASW ship doesn't drown its own passive sensors with self-noise. Ways of reducing radiated noise include:

- being able to run the vessel via an electric drive, rather than the gas turbines normally used for propulsion (that, of course, is the same trick that conventional submarines use)
- designing the hull to reduce flow noise

- designing the ship's internal systems in detail to reduce the sound levels produced by machinery and other systems, including by carefully designing pipelines to reduce fluid flow noise in the piping
- isolating internal systems from the external hull so that noise that's produced by internal systems isn't transmitted into the surrounding water.

The first of those methods is binary: either a ship has an electric drive capability or it doesn't. All the others are a matter of degree, and there's no modern warship design that completely ignores those principles. However, as observed above, optimisation is often expensive and engineering trade-offs have to be made between performance, cost and maintainability. Because of the history of their designs and the overall mission set, the SEA 5000 contenders seem to involve different levels of compromise.

Acronyms and abbreviations

ADF	Australian Defence Force
ASW	antisubmarine warfare
AWD	air warfare destroyer
LHD	landing helicopter dock
NATO	North Atlantic Treaty Organization
RAN	Royal Australian Navy
SSN	nuclear-powered attack submarine
VLS	vertical launch system

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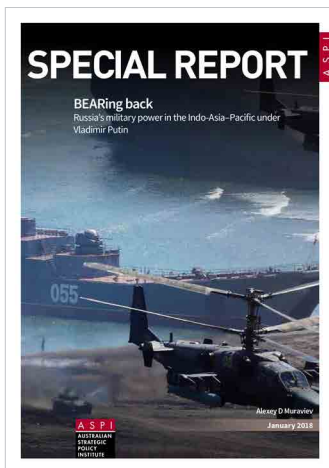
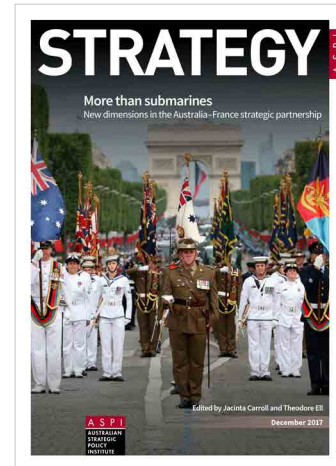
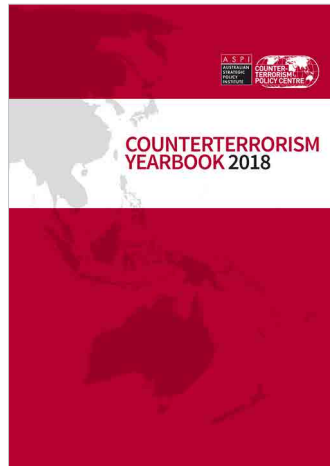
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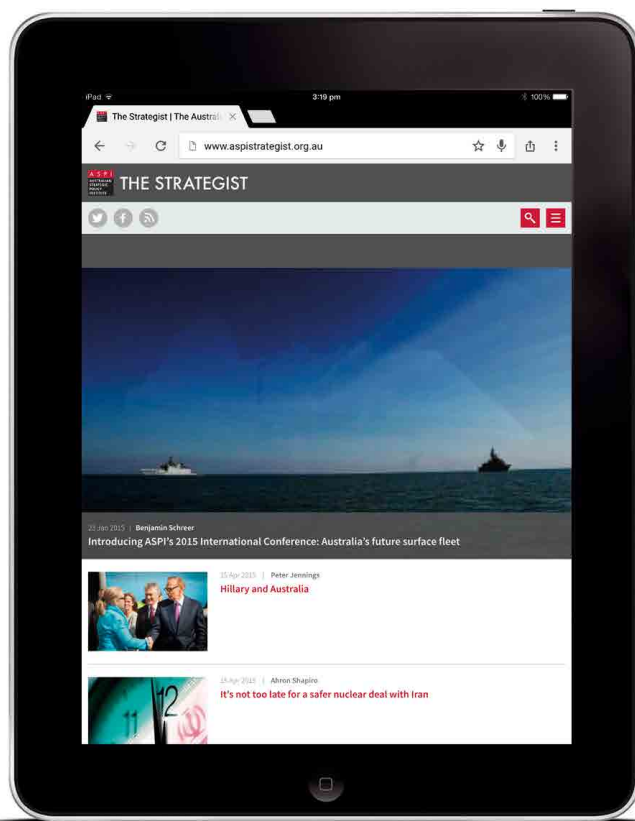


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