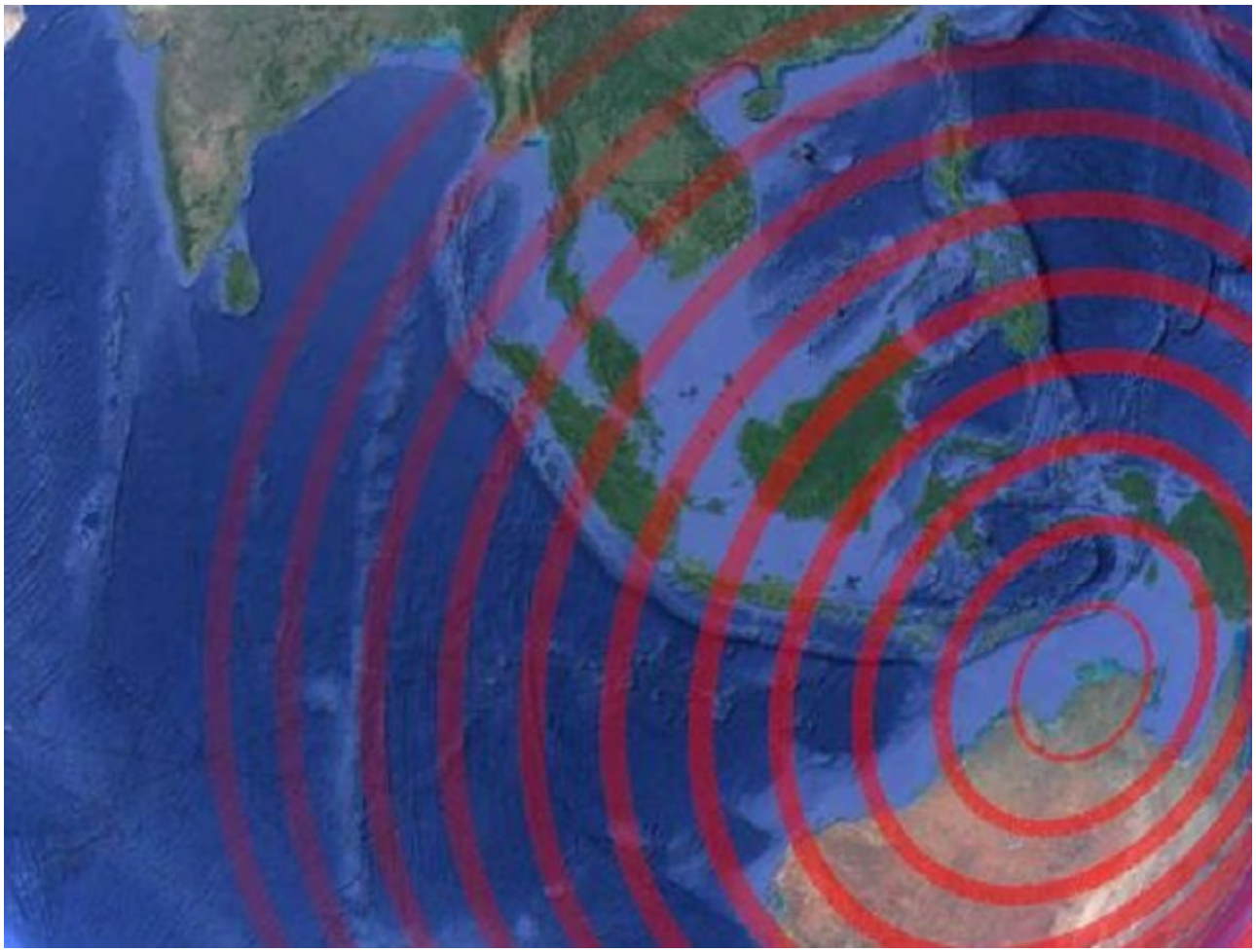
AUSTRALIA’S FUTURE SUBMARINES: AN EXPLAINER



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ALLAN BEHM, REAR ADMIRAL PETER BRIGGS (RETIRED), COMMODORE PAUL GREENFIELD RAN (RETIRED)

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I. INTRODUCTION

In this report, the authors identify the principal factors that need to be identified and addressed if Australia is to pursue the nuclear propulsion option for its next generation submarines. They conclude: “The most important consideration is ensuring that the solutions adopted do not create unintended consequences, and that opportunity costs (the things we do without if we are to have the things we want) are not counter-productive.”

The authors of this paper have long been involved in advising successive Australian governments on submarine policy and acquisition strategies. Rear Admiral Peter Briggs (ret’d) and Commodore Paul Greenfield (ret’d) have extensive operational experience in the submarine arm of the Royal Australian Navy, and all three authors (together with Commodore Terry Roach and the late Rear Admiral Oscar Hughes) delivered a major technical study—*The Future Underwater Warfare Capability, Industry and Political (FUCIP) Study* —to the Department of Defence in 2006.

This study was published by The Australia Institute **here**

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Banner image: Nautilus Institute 500 km concentric radii from Darwin using Range Rings for GoogleEarth

NAPSNET SPECIAL REPORT BY ALLAN BEHM, REAR ADMIRAL PETER BRIGGS (RETIRED), COMMODORE PAUL GREENFIELD RAN (RETIRED)

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Contents

Summary

The proposal that Australia should acquire nuclear-powered submarines raises a host of problems so inordinately tricky that their solutions are bound to be incomplete and highly fluid. “Wicked” problems such as these generate messy solutions, and their resolution—insofar as complete resolution is possible—requires the understanding of relationships between intersecting issues.

This paper endeavours to identify the principal factors that need to be identified and addressed if Australia is to pursue the nuclear propulsion option for its next generation submarines. Australia has the capacity to manage these issues, even if it cannot resolve them absolutely. And as a wealthy country, we can certainly afford nuclear-propelled submarines.

Regardless, cost is not the principal concern. The most important consideration is ensuring that the solutions adopted do not create unintended consequences, and that opportunity costs (the things we do without if we are to have the things we want) are not counter-productive.

Introduction

The decisions of the Turnbull government to acquire 12 conventionally powered submarines from France and that of the Morrison government to cancel the French contract in favour of at least eight nuclear-powered submarines from either the US or the UK have generated an astonishing amount of commentary. There has been some criticism of these decisions, but mostly there has been confusion.

The politics of the submarine issue have inundated most of this commentary, undermining any possibility of a broadly shared national understanding of the policy issues that underpin such a strategically momentous, technologically ambitious and financially demanding capability acquisition.

It has become clear in recent months that there is a variety of attitudes and approaches amongst those who claim expertise in strategic policy, defence force structure, capability acquisition, systems management and submarine operation to the evaluating the merits of the different options available—and that many of these approaches are quite different to the basic principles that should guide such a critical investment:

- Both supporters and critics of the currently in-service Collins class submarine, for instance, both bring a variety of views to the table that ensure contestability in the policy domain while delivering little clarity to the issues involved.
- Supporters and critics of the Shortfin Barracudas—the diesel-powered submarines that Australia originally committed to buy from France—both advance assumptions that remain, given the cancellation of the program, largely untested.
- Proponents of nuclear-powered submarines—generally either the US Virginia class or the UK Astute class nuclear-powered attack submarines (SSNs)—also bring technical views to the table.
- And finally, the few advocates for the French Barracuda nuclear-powered submarine have yet to explain exactly how Australia might construct and operate a capability that might be considered an even greater departure from the traditional approach to major capability acquisition, which involves close alignment with a major (i.e. “Five Eyes”) ally.

Perhaps disrupted times demand disruptive solutions that test long-held assumptions.

The Australia Institute has identified a need for some background explanation to assist people interested in this issue. This paper aims to help the public to come to a more informed position regarding the following:

- The strategic basis of Australia’s defence policy;
- The place of submarines in Australia’s force structure;
- The tasks that submarines might be expected to perform;
- The trade-offs entailed in selecting either a conventionally-powered or a nuclear-powered vessel;
- Australia’s industrial capacity to construct and maintain submarines (conventionally-powered and nuclear-powered);
- The approximate costs that might be associated with both options; and
- The associated national sovereignty issues.

The authors of this paper have long been involved in advising successive governments on submarine policy and acquisition strategies. Rear Admiral Peter Briggs (ret’d) and Commodore Paul Greenfield

(ret'd) have extensive operational experience in the submarine arm of the Royal Australian Navy, and all three authors (together with Commodore Terry Roach and the late Rear Admiral Oscar Hughes) delivered a major technical study—*The Future Underwater Warfare Capability, Industry and Political (FUCIP) Study* —to the Department of Defence in 2006.

Background

The last major Ministerial statement on the place of submarines in Australia's strategic policy and force structure was made in late 2009, when the Hon. Greg Combet, the then-Minister for Defence Personnel, Materiel and Science addressed The Sydney Institute. With considerable prescience and even more understatement, Combet said:

Submarines represent incredibly challenging demands in the combined fields of personnel, acquisition and procurement, and science. The future submarine project is itself perhaps at the margins of Australia's present scientific and technological capacity. We should not ignore the demanding nature of this project, which will require every bit of scientific, technological and industrial capacity that Australia can muster. And we will inevitably require assistance from our allies to succeed.[1]

Over a decade later— with no new submarines designed, constructed or launched in Australia in the intervening period—the complexity of the issue, and the enormity of its demands on Australian industry and know-how, has become even more challenging. At this point, a quantum leap in Australia's submarine acquisition ambition is needed if we are to reach the goals set out in the Force 2030 white paper[2] to which Combet's speech related.

In 2014, with a view to short-circuiting the technological and industrial complexities of submarine acquisition, the Abbott government considered purchasing Japan's Soryu Class at a notional cost of $20 billion[3]. However, only two years later, the Turnbull government contracted with the French government to undertake an *ab initio* design and build for a new submarine, to be known as the Shortfin Barracuda class, at an estimated cost of $50 billion. As a result, the overtures to Japan ended in embarrassment. So, too, would the contract with the French government: the announcement last year of the AUKUS agreement, and the resultant cancellation of the Shortfin Barracuda purchase, led to a diplomatic contretemps with France for both Australia and the US.

The public is entitled to question whether a capability as costly as a submarine force rests on solid strategic and policy underpinnings if it can be handled in such a cavalier way, and whether a commitment with unknown long-term costs can be made without the detailed strategic and financial justifications that the electorate should expect.

Strategic policy considerations

Australia's security is a function of its geography, the strength of its economy, the wisdom of its leaders, the quality of its foreign policy, the capacity of its defence force and security agencies, and the determination and resilience of its people.

Australia remains one of the most secure nations in the world. We are afforded natural security advantages by our geographical position, our lack of land borders with any neighbouring country, and our remoteness from both the historical theatres of conflict and the powers that conduct such conflict. Australia has no enemies, and there is no nation in the world that threatens an armed attack against Australia, far less an invasion of the Australian continent. There is no political or strategic issue that might generate armed conflict between Australia and any other nation, such as the claim and counter-claim for the Falkland Islands that remains an irritant between Argentina and the UK,

the competing territorial dispute between Japan and Russia regarding the Kuril Islands, or the three-way dispute between China, Japan and Taiwan concerning the Senkaku Islands.

Australia has, however, long been preoccupied with perceived or possible threats to its sovereignty and territory, and pays considerable attention to security matters in general and defence matters in particular. Australia's involvement in two World Wars reflected both the bipartisan position of successive Australian governments that major conflicts in Europe and Asia affected Australia's security and the palpable sense of dependence on Britain's imperial power. With the failure of British imperial power in Singapore, Australia turned to the US as its principal protector.

The instability that followed the end of World War II in Asia prompted the Chifley and Menzies governments to pursue a policy of forward defence. Australia's defence forces were constructed around expeditionary capabilities to enemy territories in support of allies, especially the US, rather than contemplating a national defence posture predicated on military operations to be conducted from, or even on, Australian soil. The Korean War (1950-53), the Malayan Emergency (1948-60, with Australia engaged from 1955-60), the Indonesia-Malaysia Confrontation (1963-66) and the Vietnam War (1954-75, with Australia engaged from 1962-72) were each, in different ways, expressions of this forward defence policy.

The political and social impacts of the Vietnam War—along with the spiralling cost of weapon systems and the increasing complexity and sophistication of both weapons and platforms—led the Whitlam, Fraser and Hawke governments to embark on a lengthy review of the foundations of Australia's defence policy. Expressed in a series of classified technical studies (referred to collectively as the Defence of Australia Studies), this process culminated in the Defence of Australia doctrine promulgated by Defence Minister Kim Beazley in 1986, following a review conducted by Paul Dibb. This policy mandated a focus on the Australian Defence Force's ability to operate decisively in the sea-air approaches to the continent, thereby denying any adversary the ability to attack Australia directly, occupy Australian territory and force Australia to accept foreign domination.

As Beazley recognised, Australia's size and the ocean spaces that separate us from other theatres of war confer natural advantages. They impose major operational demands on any would-be adversary. But they also impose operational demands on Australia itself. In particular, Australia needs to turn the uncertainties that would confront any adversary to its own advantage: it needs to combine stealth, surprise and lethality to achieve its strategic purposes.

The question nonetheless remains: how does Australia contemplate the defence of approximately 4.5% of the earth's surface[4] (i.e. 1.5% of the world's landmass and 3% of the oceans and seas, including our exclusive economic zone) with just 2% of the world's total wealth[5] and 0.3 percent of the world's population? The sums are confronting. In Australia's case, "bang for the buck" really matters, depending as it does on the generation of decisive lethality that both deters a would-be adversary and defeats that adversary should it resort to the use of armed force.

The answer to this question lies in a deep analysis of Australia's national interests and strategic objectives. It is a truism, perhaps, to observe that strategic planners often re-fight the last war, premising their force structure prescriptions on perceived inadequacies of or limitations on the systems available to force commanders at the time. While "lessons learned" may indeed feed into force structure design, an even greater temptation is to base critical force structure decisions on threats, real or perceived. Threat-based planning has long been a preferred approach to force structure design,[6] and many countries premise their defence policy and capability decisions on classified intelligence outlooks that scan the threat horizon and inform the probability calculations that may ultimately decide the trade-offs inherent in capability decisions. This approach has

exercised considerable influence on decisions about Australia's defence capabilities.

But threat-based planning is reactive planning: it brings with it a constant focus on response and control (where possible) on rates of escalation. Its essence is captured in expressions like "responding within the adversary's decision-loop" and "beating them to the draw". This is fine if war is fought against a predicted adversary. But what if it is not? What if the predicted threat never materialises, and is instead superseded by an altogether different, unforeseen threat?

Strategic planning takes a different approach. Instead of looking for threats, it focuses on the nation's strategic objectives and how they are best to be realised. This is a more complex task than responding to threats, because it necessarily factors in dimensions such as values, interests, purpose and goals. In recent years, this approach has encouraged the development of a range of analytical tools that stress-test strategic objectives by subjecting them to scenario-based (as distinct from threat-based) evaluation. One such technique called "Massive Scenario Generation",[7] developed by the RAND Corporation, has been used to considerable effect, at least in the US.

Australia's strategic planning must comprehend two quite different macro-objectives, where the difference between proximity and remoteness has enormous operational consequences :

1. How does Australia deter and defeat an adversary in the western, northern and eastern maritime approaches to the continent lying principally between the equator and the tropic of Capricorn?
2. How does Australia deter and impose major operational constraints on an adversary close to the adversary's major bases, which may be well north of the equator?

Vladivostok, for instance, is 4,800 km north of the equator, while southern Hainan is 2,000 km north of the equator. But for an Australian submarine to operate in the Sea of Japan or the South China Sea, the navigable distance would be in the order of twice to three times those distances, given the need to choose navigation routes that afford maximum security and safety to the submarine during deployment.

The operational constraints are huge. Given an average deployment of 70 days, an Australian-based submarine would achieve about 25 days on station in the Northern Hemisphere in a time of high military tension. In the Southern Hemisphere, it would achieve about 50 days on station.

In both cases, the force structure implications are also massive. For Southern Hemisphere operations, Australia would require a minimum of 12 operational submarines to maintain a permanent presence 3000km distant from home ports on the eastern and western seaboards. For Northern Hemisphere operations, Australia would require a minimum of 30 operational submarines to maintain a permanent presence at 9000km from home ports. And when the training and sustainability demands are considered, these numbers increase by approximately 50%.

It is inconceivable that, in achieving these two macro-objectives, Australia would be conducting its defence absolutely on its own, with no one else affected except the adversary and us. In North Asia, Japan and South Korea at the very least would also be engaged. And even if we were absolutely on our own, it would be impossible to achieve these objectives with a submarine force of eight boats. To maintain a minimum operating capability of six boats, we would need at least 18 submarines (six on operations, six in maintenance and six in work-up and training)—without taking attrition into account.

The issue here is not simply one of affordability. Rather, it is one of the opportunity costs associated with maintaining a substantial submarine fleet significantly bigger than the surface combat fleet of

eight frigates and three destroyers.

Defence capability and force projection

In common with other nations with relatively small populations, Australia needs to marshal its defence resources in such a way that it gets the biggest return in terms of both deterrence and force effects that its financial investment can deliver. It needs a mix of forces that support agility and flexibility while imposing the maximum strategic risk and operational costs on any potential adversary.

This objective demands a mix of defensive and offensive forces that exploit our natural strategic advantages while limiting an adversary's ability to exploit time and distance. The sinking of Russia's Black Sea flagship RTS Moskva by Ukrainian forces in April 2022 offers a recent example of how carefully shaped offensive forces can inflict a disproportionately large strategic loss.[8]

Any attempt to apply armed force against Australia would require an adversary to deny Australia the ability to operate in its proximate air spaces and waters, while also controlling the air and sea approaches to Australia. Such a situation is known as "sea denial" (which hinders an adversary from operating effectively) or "sea control" (where an adversary is completely prevented from operating at all).

To achieve this, an adversary would need to secure land facilities within strike range of Australia's points of vulnerability—which would effectively require the adversary to control the land arc stretching from the Cocos Islands in the Indian Ocean to the Solomon Islands in the Pacific. It also needs to be able to operate its major naval assets without fear of disruption and loss at the hands of Australia's maritime (air and sea) capabilities.

These two strategic demands combined demonstrate just how formidable a task the strategic subjugation of Australia would be. Japan's historical occupation of the island chains to the north and east of Australia, together with its attempt to exercise sea control in the Coral Sea, were premised on keeping Australia out of the Pacific war, rather than its occupation and defeat. Yet Japan was unable to achieve even this more limited strategic objective.

By any measure, Australia has a creditable record in designing and delivering a balanced suite of capabilities with which to defend its sovereignty and its landmass. Notwithstanding Australia's long history as a significant contributor of land forces to global conflicts and distant peace-enforcement and peace-keeping operations, air and maritime forces have maintained high capability and operational standards.

The role of submarines

Since the time of Alfred Deakin's Prime Ministership, the second of which ended in 1910, submarines have been recognised as a key force structure element. Prior to and during World War II, Australia was unequipped and unprepared for underwater warfare. Since the mid-1960s, however, Australia has operated advanced conventionally-powered submarines successfully, beginning with the Oberon class[9] and continuing to the Collins class.[10]

Successive Defence White Papers have reiterated the critical role played by submarines in Australia's defence. The most recent extended policy treatment of submarines was delivered in the 2016 Defence White Paper, which had this to say about submarines:

Submarines are an essential part of Australia's naval capability, providing a strategic advantage in terms of surveillance and protection of our maritime approaches. The Government has determined

that regionally superior submarines with a high degree of interoperability with the United States are required to provide Australia with an effective deterrent, including by making a meaningful contribution to anti-submarine warfare operations in our region … The Government will increase the size of the submarine force from six to 12 boats. The doubling in size of the submarine fleet recognises that Australia will face a more challenging maritime environment in the decades ahead. By 2035, around half of the world's submarines will be operating in the Indo-Pacific region where Australia's interests are most engaged. Australia has one of the largest maritime domains in the world and we need the capacity to defend and further our interests from the Pacific to the Indian Oceans and from the areas to our north to the Southern Ocean. Submarines are a powerful instrument for deterring conflict and a potent weapon should conflict occur.[11]

While the passage of time and intervening events have rendered the White Paper's plans for submarine delivery in Australia unachievable, the basic policy arguments stand.

For Australia to exploit stealth, surprise and decisive lethality from the relatively secure facilities available to it on its own territory, submarines are essential. They offer the Government of the day unique responses across the range of scenarios, and exhibit a range of core capabilities that no other individual platform can match.

Stealth

During peace time, submarines offer a unique capability to monitor and survey a potential adversary's preparations, training and readiness. During a period of tension they can add specific indications and warning to this capability and deter an adversary from escalating the situation to conflict. In the event of hostilities, they offer great lethality and uncertainty, impacting on an adversary's freedom to act.

In all these situations, the submarine's stealth makes it a unique platform, able to operate unobserved and if required, offensively where we do not have sea or air control. In terms of offense, defence and the delivery of decisive lethality in Australia's maritime approaches, submarines present a unique set of tactical problems to adversaries. They are supremely difficult to detect and track, and their defeat demands the deployment of substantial Anti-Submarine Warfare (ASW) resources that would greatly expand and complicate the attack forces that would be required to subjugate Australia.

Strike capability and deterrence

For Australia's defence—when working in combination with space-based, aviation and long-range land-based strike systems—submarines offer an optimal strike capability. Let us consider these attributes in greater detail.

- Submarines can operate in areas where Australia is unable to maintain either sea denial or sea control.
- Submarines can monitor, collect and evaluate undersea and above surface intelligence; position themselves to deliver decisively lethal force against an adversary; and generally constrain the ability of an adversary to deploy its sea power.
- Submarines offer a unique ability to maintain reconnaissance, surveillance and strike options.
- Submarines impose disproportionate costs on an adversary and increase that adversary's strategic uncertainty as it tries to detect and counter the threat generated by submarines.
- Hence submarines have a significant deterrent effect at the strategic level of war, and greatly

restrict an adversary's ability to take the initiative at the tactical and operational levels of war.

Submarines combine a singular set of attributes: stealth, surprise, paralysing force effects and, most importantly, an ability to degrade the decision-making capacities of the adversary.

These impacts are even greater closer to the adversary's operating bases and associated training areas. As such, Australia needs a substantial submarine capable of meeting the demands of range, endurance and payload.

Range, endurance and payload

Range, of course, is critical, since submarines are characteristically self-supporting, and need to be able to extend their presence over considerable distances. Range is but one factor, however. Dived endurance is what leverages range to deliver decisive lethality. A submarine is most vulnerable when surfaced, and conventionally-powered submarines that need to surface to "snort"—recharge their batteries—are required to do so frequently. Modern submarines with air independent propulsion (AIP) can remain submerged for longer periods, but still need to surface to recharge.

Combining mobility (fuel and energy), habitability (food and crew support systems), deployed sustainability (power, cooling, spares, onboard repair/support capacity) and the availability of sensor weapons systems, a submarine is effectively an autonomous system.

To assure a submarine's effectiveness, payload is the other key demand. This combines the size of the crew (and its necessary specialist skills), the numbers and variety of weapons, remotely operated vehicles and systems (the critical force-multiplier for the next generation of submarines), together with redundancy and space for systems expansion over the life of the submarine.

The advantages of nuclear submarines

Nuclear powered submarines have two distinct advantages over conventional submarines: limitless high speed (a key factor in affording extended range) and freedom from the surface while deployed. Both are significant advantages given Australia's geography and the long distances entailed. As discussed above, conventionally powered submarines must surface regularly to recharge their batteries. A nuclear-propelled submarine has no such requirement, and as such, its submerged endurance is limited only by food and crew effectiveness.

The removal of the need to surface also allows it to travel long distances quickly—and in modern undersea warfare, speed is crucial. Once detected, submarines are particularly vulnerable, and the ability to evade attacks with agility and stealth is key to survival—for the submarine and its crew. Nuclear submarines are significantly swifter than their diesel counterparts, and this is one of the strongest arguments for the introduction of nuclear-powered propulsion for the next generation of RAN submarines.

But speed can be traded off against stealth, particularly as conventionally-powered submarines can be significantly quieter than their nuclear-powered counterparts. There is a complex relationship between a submarine's size, weight, endurance, speed when submerged, stealth characteristics, and the size of its crew. Working out the optimum configuration of all these factors demands a high degree of definition and resolution before any final decision can be taken on a new platform and its propulsion system.

Force structure consequences

Trade-offs are integral to force-structure planning. Capabilities with long acquisition and support cycles need more investment than those that can either be acquired in short timeframes or do not require high continuing states of readiness. Because of the distance of their bases from the theatres of operation and their long transit times, submarines cannot be brought into force projection and offensive roles quickly. So the capability demands greater numbers and higher (and more expensive) states of readiness than simpler technologies.

Were any Australian government to invest in a high-readiness submarine capability that afforded an ability to maintain submarines on station at considerable distances from Australia, the force structure consequences would be considerable. Either or both of two outcomes would be inevitable: existing capabilities across the ADF would need to be reduced or "mothballed" to enable large re-investment into an expanded submarine capability, and/or significant additional budget outlays would be required to fund the expanded submarine force.

In assessing the force structure consequences, there are many unknowns. The size of the submarine, its propulsion system, design and related R&D costs cannot at this point be estimated accurately. But if experience is any guide, we do know that the overall cost of a new and technologically complex system will be enormous. The Australian Strategic Policy Institute has estimated an out-turn cost range of $153-171 billion.[12] We shall see.

How a submarine is built

The design of submarines (and therefore the key cost drivers) begins with the customer navy's requirements, bounded by an interlocking set of assumptions and constraints. These requirements are based on the missions the submarines will undertake. There could be about a dozen key design and cost drivers, which might include:

- Range and endurance (based on mission profiles);
- The duration of transit from the home base to the operational area (based on a transit regime);
- Ship's company numbers (for accommodation, consumables and emergency stores);
- Special solutions required such as specific sonar arrays, combat systems and weapons (e.g., in Australia's case, the US-sourced combat system and torpedoes);
- Survivability targets, including stealth (visual, thermal, acoustic, electronic and magnetic signatures);
- Shock standards for all structures and components, especially relating to underwater explosions adjacent to the vessel; and
- Affordability targets for construction and through-life repair, maintenance and upgrade activities.

For a diesel electric submarine, the indiscretion ratio (the proportion of time spent charging main storage batteries) is a key consideration. It dictates generator/battery capacity, which is a key determinant of the size of the submarine.

The design process is iterative. It starts with the big picture (a concept design), to which is added specific equipment and systems. Some of this might already be available from the market—for example, diesel generator sets, propulsion motors, main storage batteries, combat systems and sonar arrays and weapons. Others might need to be developed.

Once the systems are finalised, the design is adjusted to find a buoyancy (how the vessel maintains stability when submerged), trim (how the vessel remains "on an even keel" when submerged),

power and heating/cooling equilibrium. Ideally, this is done while ensuring that each iteration meets the customer navy requirements, but if this is impossible, compromises can be agreed. With each iteration, the design includes more details, and the eventual final iteration manoeuvres towards a perfectly balanced solution.

If equipment is not available from the market—as was the case for the Collins class, due to its sheer size and singular design—then either existing equipment must be modified (e.g. the Collins' diesel generator sets) or new machinery and equipment must be designed and manufactured (e.g. the main propulsion motor, batteries, switchgear). The delivery and operational risk increase as more machinery needs to be designed from scratch.

Engineering Challenges for Australia

So how might the process described above play out for an Australian submarine?

The first key drivers for Australia are range and endurance. These are derived from long and distant patrols, with annual mileage four or five times that of northern hemisphere conventional submarines. Australia's submarines need to be large enough to carry the fuel, stores, weapons and consumables and, critically, appropriate crew numbers. The crew size must be sufficient to cope with possible contingencies and to manage fatigue over a 10-week patrol without compromising the mission. To maintain the strictest of neutral buoyancy under all conditions, the compensating tank sizes must allow the submarine to achieve neutral buoyancy despite changes due to fuel and food consumption, launching of torpedoes and missiles, changes in seawater density due to temperature and salinity, and compression of the hull during deep dives.

Size really matters for an Australian submarine. It must be large enough to carry and sustain the crew required for the mission—which means that it must be a large submarine. The larger a submarine, the more consumables are needed. The further afield the patrol area, the more fuel is needed. The warmer the waters in the patrol area, the more cooling needs to be installed, and the larger batteries needed require greater installed generating power to minimise the indiscretion ratio.

In general, a large submarine should be easier to detect than a small one, because it would have a larger sonar target echo strength and there would be more noise generated from the larger power plant. These are areas of engineering looking for solutions to this issue. Some solutions include acoustic tiles to reduce target echo strength, the inclusion of chines (sharp edges) separating flat facets on the hull and fin in a manner similar to that on stealth bombers—an approach used in the latest Swedish and Chinese submarine designs[13]—and mounting rotating machinery on heavy isolation rafts. (The Collins has elastically mounted rafts on which machinery, accommodation spaces and equipment, are all installed.)

A smooth hydrodynamically shaped hull increases efficiency through the water, reduces power consumption and will improve fuel efficiency and range. It will also reduce flow noise, which increases with speed, and hence improve the limiting sonar listening speed, above which the sonar arrays are effectively deafened and unable to detect targets.

To maintain detection range advantage over another submarine, the large hull size must be used to fit the largest sonar arrays possible. This, with the right computer processing, will significantly increase detection ranges.

Submarines need to be "all ears," and be very stealthy, which is a normal focus of submarine designers—or should be. For Australia, though, there are other issues that pose engineering

challenges that need to be solved.

For a diesel electric submarine, the time spent running diesel engines to charge batteries at periscope depth must be minimised to avoid detection by an adversary. Modern northern hemisphere submarines are fitted with Air Independent Propulsion (AIP), meaning they can exit a harbour and immediately undertake a two-week patrol, entirely on batteries and AIP, without having to resort to charging the batteries with diesel engines. But this only works because their patrol area is very close to their own ports.

Australia's submarines must transit for thousands of miles before commencing a patrol and they are exposed every time a snorkel is raised to run the diesels for battery charging. This could occur every few days, daily or several times a day, depending on transit speed. Charging the batteries makes a submarine vulnerable to detection and attack, so the need to do so must be minimised. The solution is having as large a battery as possible, matched with a maximum of installed power generation to charge the batteries in the shortest time possible.

Even with modern lead-acid batteries, anything better than 70% of the battery's full theoretical capacity can only rarely be achieved in practice on long patrols. Also, Australia's long transits create other problems for the batteries, such as the fact that the constant "deep cycling" of the battery on the way to the patrol area will already have reduced the available battery capacity substantially before the real work starts. It also means the operating life of a such a battery is drastically reduced.

This is an Australian engineering challenge which is not a priority for other navies.

Some argue that lithium-ion batteries would solve this problem, because unlike lead-acid, lithium batteries have full power available until nearly flat and the batteries can be fully charged quickly, which reduces the indiscretion ratio. But the reality is not so simple.

The heavy lead-acid battery banks are a key stability feature. It is impossible to preserve stability while replacing the heavy lead acid batteries with light lithium-ion batteries is not possible. This means that a submarine must be designed from the start for lithium batteries. While the number of such submarines is increasing, none face the long transits to the patrol area that Australia must deal with. Also, lithium-ion batteries are highly sensitive to heat and can suffer "thermal runaway", resulting in a fire which cannot be extinguished. For an Australian submarine, it would be very difficult to mount a successful safety case for fitting lithium-ion batteries.

There is hope in emergent battery technology. For example, nickel-zinc batteries, which have a similar weight to lead acid batteries may offer most of the advantages of lithium-ion without the disadvantages. Such batteries could also be designed as "drop-in" one-to-one replacements for existing lead acid batteries. This would provide a substantial and very beneficial performance improvement relatively simply for submarines like Collins.

Apart from machinery noise transmitted into the surrounding ocean, radar echoes and wake from the periscopes and masts can also give a submarine's game away. The more diesel generating power is installed on a boat, the greater the diameter of its diesel engine air induction mast needs to be, and the greater its vulnerability to radar and wake detection. This requires special stealth treatment, and/or a practical means to reduce the induction mast diameter.

At the outset, affordability targets such as cost per tonne for construction, and operating costs, need to be understood and set. Both The Department of Defence's records and those of ASC Pty Ltd (which built the Collins class submarines) show that the final cost per tonne for that boat's construction was marginally less than the global average at the time. This was largely due to the

Swedish construction method, which also produced a design with world class stealth characteristics. This very cost-effective construction method lent itself to reduced costs for routine heavy maintenance and upgrades in later life.

Keeping the cost of maintenance reasonable during the life of the submarine is more important than the purchase price, because the acquisition cost is typically only about one third of the total cost of ownership through life. A useful comparison for this through-life maintenance cost, which is in global use for factories, operating plant and fleets, is the percentage of net replacement asset value spent annually, or %RAV.[14] While most navies, including Australia's, do not seem to use this metric, the French Marine Nationale is understood to aim for 5%RAV for their Rubis class fleet of small nuclear powered attack submarines. For the Collins class, the figure is about 7%, but this covers more than just the submarines themselves.

Budgets do tend to be "starved" of funds, however, leaving mountains of uncompleted preventative maintenance work, an unnaturally high outstanding defect list, and broken submarines which cannot be used. This leads to the vicious cycle of low submariner morale, high attrition and poor recruiting, problems that the Collins class submarine has faced in the past.

Propulsion

Australia's conventionally powered submarines are world leading in their class. Conventional submarines can undertake all the tasks that the Australian government might realistically require of them. One might therefore ask why we need new submarines at all.

That question, however, can be met with another question: could those tasks be undertaken more effectively? The answer to the latter question is "yes". Nuclear propulsion for its submarines would afford Australia major benefits in terms of range, speed, time on task and operational flexibility. In particular, nuclear propulsion would afford a significantly increased level of survivability for any submarine that might be detected: a conventional submarine travels underwater at 20 Knots (40 Kph), but can only do so for a short time—typically less than an hour—before the battery is depleted. A nuclear-propelled submarine can travel underwater at about 30 knots (say 60 kph) continuously if required, its endurance is limited by food and crew effectiveness.

Nuclear reactors also radically change the power available to submarines, their endurance underwater, the transit times and time on station, as well as the "hotel" services available to submarines and their crews. Combat system capability, habitability, air quality, water availability and general amenity are much enhanced. There is much to be said for nuclear propulsion, especially when the submarine's survivability and that of its crew is taken into account. The cost multiplier, however, may not match the force multiplier effects.

Nuclear propulsion would also raise a host of new and imponderable issues for Australian industry, and for the RAN's ability to support the submarine. Lacking a nuclear industry—and thus the education and associated skills streams that support such an industry—Australia would necessarily have to develop the education, infrastructure and industrial support needed to maintain the capability as part of the cost of that program. It would be important that Australia develop a sovereign capability in all these areas, as the availability of third parties in a time of tension is moot.

At present, the Royal Australian Navy (RAN) has no nuclear qualified personnel. The nuclear-powered attack submarines (SSNs) and the ballistic missile submarines (SSBNs) in service with the USN and the Royal Navy require between 40 and 50 crew members qualified at varying levels of nuclear expertise per boat, with considerable numbers of similar personnel in the logistics and support functions ashore. Maintaining the pipeline of nuclear-trained personnel in the US or the UK

will be costly—approximately $1 million per person per year. Establishing and maintaining a similar pipeline in Australia will not be significantly less expensive.

In June 2022, the US House of Representatives introduced legislation that would assist the RAN to train its future submarine operators in the US: the Australia-US Submarine Officer Pipeline Act will permit at least two Australians to train in the US each year.[15] This is an important, but ultimately token, effort. The pipeline will need to be as wide as it is long to remediate the shortfall in the RAN's skill base.

It is important to recall that the UK and USA established their SSN capabilities in the circumstances of the Cold War, drawing upon a large force of conventionally powered submarines and steam powered surface ships. This situation assisted in providing the essential manpower and skills base. Nonetheless, the task was a serious challenge for each navy.

Australia has none of these resources and will have to draw heavily on the supplier navy's training system and seagoing submarine force to train its personnel. The availability of the necessary level of support would be a major risk for an Australian SSN program, and one that needs early resolution.

Equally importantly, the numbers and skillsets in an SSN crew are significantly different to that of a Collins crew. The training program would entail converting existing RAN submarine personnel and a substantial initial training program. Both would require long periods of training and overseas service to gain the necessary experience. Until Australia's SSN force reached sufficient operational submarines to undertake the at sea training of trainees (say, at least six SSN) most of this training would have to be conducted overseas—and it would take about 20 years to deliver this number of SSNs after initiating the program.

At this point, RAN schools and a nuclear engineering faculty established within a selected Australian tertiary institution could finally begin to take over this task. But in the absence of any nuclear power generation industry in Australia, the cost of establishing and operating this training infrastructure would be borne by the SSN program.

The problem is enormous.

Nuclear Safeguards

Both the Morrison and Albanese governments have declared that the nuclear-propelled submarines that might result from the tripartite Australia-United Kingdom-United States (AUKUS) agreement will be subject to International Atomic Energy Agency (IAEA) safeguards. The Nuclear Non-Proliferation Treaty (NPT) proscribes the acquisition of nuclear weapons by Non-Nuclear Weapon states (NNWS), and prescribes that all nuclear materials under the control of NNWS be subject to safeguards to ensure that there is no diversion of nuclear materials to nuclear weapons use. The NPT does not preclude the non-explosive use of nuclear materials, as in naval nuclear reactors. It is an interesting feature of the IAEA safeguards system that safeguards procedures are suspended while the nuclear material remains in military use. Once the nuclear materials are removed from non-explosive military use, however, safeguards again apply.

Just how Australia might negotiate a comprehensive safeguards agreement with the IAEA is by no means clear. At this point, no other country has negotiated such an arrangement with the IAEA. So for Australia and the international community alike this would be a "first". There would be considerable international scrutiny, with regional countries such as Indonesia, Malaysia and New Zealand paying close attention to the implications for their Nuclear Weapon Free Zone arrangements, and China probably opposing any non-explosive military use exemption for Australia

to preclude any knock-on effect that might arise were Japan or South Korea to seek to follow a similar path.

The Morrison and Albanese governments have also announced their intention not to develop a nuclear industry in Australia to support nuclear propulsion, but rather to acquire propulsion plants that could provide whole-of-life management of reactors. The reactors would be supplied fully fuelled and disposed of by the supplier at the end of their operational lives. As John Carlson has pointed out, "If fuel loading and unloading is monitored, and the submarines are known to be operational, adequate assurance could be established that no fuel is diverted".[16]

However, it is hard to imagine that some countries would not press for intrusive inspection regimes to ensure that there is no tampering or diversion, even if the propulsion plant were under the operational control of a third NWS party. It would be critical to put Australia's diplomats to work on negotiating an agreed safeguards arrangement that honoured the classified access requirements of the reactor suppliers and the protection of classified military operating systems by the RAN.

Eli Levite and Toby Dalton argue that the negotiation of a safeguards regime for Australia's nuclear-propelled submarines "presents opportunities to reimagine the non-proliferation regime in ways that would better match evolving conditions and to develop new norms, tools, and practices that would help detect and deter future proliferators".[17] The difficulties associated with achieving this outcome, however, are formidable.

Industry Issues

Australia lacks the heavy industrial capacity of other advanced economies such as the US, Japan, South Korea, the UK, France, Germany, Italy or Spain. There are pockets of high-tech light industrial capacity that meet high international benchmarks, but these are generally in niche industries where profitability is not dependent on low labour costs, but rather reflects innovation and entrepreneurship.

Australia's ship-building industry, never substantial, has declined to the point of only comprising the construction of small specialist vessels, usually involving aluminium construction rather than steel. Only the naval ship-building industry has survived, supported by substantial government subsidies provided through the defence appropriation.

With appropriate (and probably significant) reinvestment, Australia could build and maintain more conventional submarines. At this point, it could not build or maintain nuclear-propelled submarines. Nor could the RAN operate them.

It might, at some future time, be possible to acquire nuclear-powered submarines on a turn-key basis, as India did from the former Soviet Union. That would require a significant transfer of sovereignty to another national power. Of course, with determination and investment, Australia could expand its naval shipbuilding capacity to produce both surface ships and submarines.

As a wealthy country, Australia can do what it wants: it just cannot do everything it wants. So decisions need to be taken as to whether the defence benefits to be derived from allocating the substantial investments required for autonomous naval shipbuilding warrant the costs, whether the expenditures involved in naval shipbuilding represent the most prudent allocation of defence spending resources, and whether the costs involved might not be allocated more efficiently to other higher priority national investments.

Personnel Issues

An increase in the number of submarines from six to, say, 12, could not be achieved with a simple doubling of the number of people in the submarine force. The critical issue is not just raw numbers, but the need for submarine crews to have sufficient sea time and operational experience to meet the demands of submarine operations safely and expertly.

Whether through boredom, lack of promotion opportunities or time spent away from family and friends, attrition rates for submarine crews can be high. The personnel demands of a larger submarine fleet would be considerable, not just across the submarine arm and the Navy more generally, but across the entire ADF. At this point, Australia does not have enough trained people to expand the submarine arm by the factor of almost three that would be required by the introduction of at least eight large SSNs. Such an expansion would require access to the US Navy and the UK Royal Navy for training and sea experience, and has a lead time **at least** as long as the time taken from concept to delivery stage.

Perhaps the critical constraint in expanding the RAN's submarine arm is the need for officers and senior non-commissioned officers trained in both nuclear engineering and the management of nuclear reactors designed for military use. In a submarine force that would exceed 1,000 sea-going personnel, supported by a naval and civilian workface numbering at least 2,000 people, the training and retention of nuclear engineers is a daunting prospect. There is a single Australian university that offers nuclear engineering as an undergraduate degree; this would require significant expansion.

Australia's capacity to supply sufficient students able to complete these demanding courses successfully remains moot. Reactor simulators can be installed to support these courses, but specific training on nuclear reactors would need to occur in the UK and the US because, notwithstanding the commonality between their systems, neither is likely to be capable of carrying the training load alone.

AUKUS

The entire submarine question has been further complicated by the introduction of AUKUS (Australia-UK-US), an acronym that suggests a trilateral relationship that is more substantial and formalised than it is in fact. At this juncture, AUKUS is little more than a political description for activities that have been ongoing for many decades. It is, however, a major distraction from the central issue: the RAN's acquisition of nuclear-propelled submarines.

AUKUS was announced with much fanfare by the former Australian Prime Minister Scott Morrison, the former UK Prime Minister Boris Johnson and US President Joe Biden on 16 September 2021. There is, as yet, no formal agreement between the parties to establish AUKUS as an entity, nor would it appear that such an entity is needed by any of the three partners. The negotiations that preceded the announcement were conducted secretly, and little is known about the exact purpose of the announcement, except to serve as the basis for cancelling the submarine purchase contract with France and initiate discussions on the acquisition of a nuclear-powered submarine from either the US or the UK.

The question is less whether AUKUS needs Australia than whether Australia needs AUKUS. The complexity of a trilateral acquisition and operation structure would almost certainly guarantee its failure. Quite simply, American, Australian and British contracting systems are very different, as are the submarine management philosophies and operating systems and structures.

AUKUS might appear to be an attractive political idea, bringing long-term allies together. As a basis for force-structure decisions, it is perhaps of doubtful utility. This is because AUKUS appears to

preclude any nuclear propulsion option but one dependent on the Highly Enriched Uranium (HEU) that powers British and US SSNs. While a Low Enriched Uranium (LEU) technology is currently under investigation by the US Navy, it is by no means clear why the US would wish to depart from a proven technology that uses 93% percent enriched uranium (i.e. weapons grade uranium) in its submarine reactor fuel rods.

France, however, uses only LEU in its submarine reactors—but whether Australia, or France for that matter, could again contemplate a submarine acquisition contract is unclear. It would be an irony if AUKUS were responsible for both the cancellation of a contract for the acquisition of a conventional submarine and the prevention of a contract for the acquisition of a nuclear-powered submarine.

Slices of humble pie notwithstanding, Australia may do itself a favour were it to broaden consideration of nuclear propulsion for its next generation submarines to include France.[18]

Conclusion

Before any Australian government can proceed to a decision to acquire nuclear-propelled submarines, there are complex systems and structural issues that must be resolved if program failure is to be avoided. These are pressing issues, with ramifications for the entire ADF force structure—and, of course, for the national budget.

The time needed to resolve these issues is considerable, and that, too, has implications for other decisions relating to the RAN's submarine force. Is the Collins submarine to be rebuilt? Is an evolved conventional submarine to be designed and built? Should Australia look to other nuclear propulsion designs, such as the French Barracuda submarine? If a nuclear-powered submarine is to be acquired, should Australia line up for "used" submarines from the US, with all the consequent risk that might involve? (Australia has not had a happy acquisition history in obtaining surplus US vessels, if the HMAS Manoora and Kanimbla purchases were any guide.)[19] If Australia is to acquire a new submarine design, either British or American, do we participate in the design process, or simply take what is on offer? And how is sovereignty maintained?

Clarity in this miasma will be difficult to achieve. Premature decisions may well be the prelude to profound strategic disappointment. Equally, deeply considered and well-grounded decisions may take Australia into an entirely different dimension of national security capability.

III. ENDNOTES

[1] Combet (2009) "From Collins to Force 2030: the challenge of the future submarine", speech to the Sydney Institute, https://webarchive.nla.gov.au/awa/20091112000335/http://www.minister.defence.gov.au/gregCombetSpeechtpl.cfm?CurrentId=9670

[2] Department of Defence (2009), *Defending Australia in the Asia Pacific Century: Force 2030*, https://www.defence.gov.au/sites/default/files/2021-08/defence_white_paper_2009.pdf

[3] McPhedran (2014), "New Japanese submarines to cost Abbott government $20 billion", news.com.au, https://www.news.com.au/national/new-japanese-submarines-to-cost-a-bott-government-20-billion/news-story/93465840a6ec374913c76fa60d3e1c7f

[4] World Economic Forum (2021), "How much of Earth's surface is covered by each country", https://www.weforum.org/agenda/2021/01/earth-surface-ocean-visualization-science-countries-russia-canada-china/

[5] Nazander (2022) “Visualizing the distribution of household wealth, by country”, Visual Capitalist, https://www.visualcapitalist.com/cp/visualizing-the-distribution-of-household-wealth-by-country/

[6] Borzillo et al (2021) *Threat-based defence planning: implications for Canada*, Network for Strategic Analysis, https://ras-nsa.ca/wp-content/uploads/2021/03/Report-on-CJOC-Defence-Pl-nning-Project.pdf

[7] Davis, Bankes and Enger (2007) “Enhancing strategic planning with Massive Scenario Generation”, https://www.rand.org/pubs/technical_reports/TR392.html

[8] Weber (2022) “Russia’s loss of its Black Sea flagship is a ‘massive blow’, and maybe also 'poetic justice’”, *The Week*, https://theweek.com/russo-ukrainian-war/1012552/russias-loss-of-its-bl-ck-sea-flagship-moskva-is-a-massive-blow-and

[9] Submarine Institute of Australia, “The RAN Oberon class: The first Australian submarine squadron”, https://www.submarineinstitute.com/submarines-in-australia/The-RAN-Oberon-Class.html

[10] Submarine Institute of Australia, “The Collins class”, https://www.submarineinstitute.com/submarines-in-australia/The-Collins-Class.html

[11] Department of Defence (2016) *2016 Defence White Paper*, p90, https://www.defence.gov.au/about/strategic-planning/2016-defence-white-paper

[12] Nicholls, Dowie and Hellyer (2022) “Implementing Australia’s nuclear submarine program”, Australian Strategic Policy Institute, https://www.aspi.org.au/report/implementing-australia--nuclear-submarine-program

[13] Newdick (2021) “China’s latest submarine seems to have lifted its sail design from Sweden’s new A26 class”, The Drive, https://www.thedrive.com/the-war-zone/41230/chinas-latest-subma-ine-seems-to-have-lifted-its-sail-design-from-swedens-new-a26-class

[14] A lower figure indicates a more efficient system. For comparison, a hotel’s %RAV would be about 1.5%; a hospital, with its surgical grade wards and operating theatres, would come in at about 4%; and a chemical plant in a hot and corrosive environment with strict safety inspection and maintenance regimes would be about 10%. A figure above 15% would indicate a maintenance program out of control.

[15] Shelbourne (2022) “New AUKUS caucus bull calls for US-Australia sub training pipeline”, USNI News, https://news.usni.org/2022/06/15/new-aukus-caucus-bill-calls-for-u-s-australia-su--training-pipeline

[16] Carlson (2021) “AUKUS nuclear-powered submarine deal—non-proliferation aspects”, Asia-Pacific Leadership Network, https://www.apln.network/analysis/commentaries/aukus-nuclea--powered-submarine-deal-non-proliferation-aspects

[17] Levite and Dalton (2021) “How the United States can use AUKUS to strengthen nuclear non-proliferation”, Carnegie Endowment for International Peace, https://carnegieendowment.org/2021/12/16/how-united-stat-s-can-use-aukus-to-strengthen-nuclear-nonproliferation-pub-86024

[18] Kuperman (2020) “France can help Albanese fix AUKUS”, The Interpreter, Lowy Institute, https://www.lowyinstitute.org/the-interpreter/france-can-help-albanese-fix-aukus

[19] See Greg Swinden, “Farewell to the LPAS”, *Naval Historical Review*, March 2012, https://navyhistory.org.au/farewell-to-the-lpas/3/ and AAP, “Cheap US ships turned out to be expensive”, 9News, 1 Jan 2017, https://www.9news.com.au/national/cheap-us-ships-turned-out-to-be-expensive/bc7588db-80c4-43b5-ba36-9a1b713ad0a1

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Nautilus Institute
608 San Miguel Ave., Berkeley, CA 94707-1535 | Phone: (510) 423-0372 | Email: nautilus@nautilus.org